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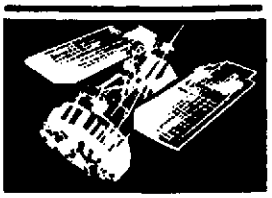
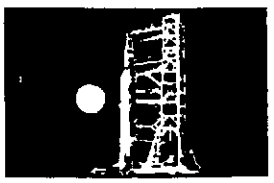
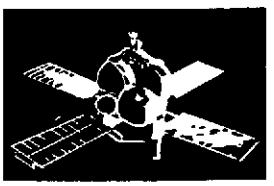
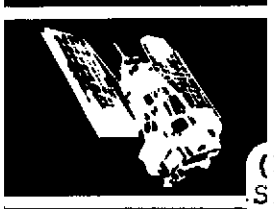
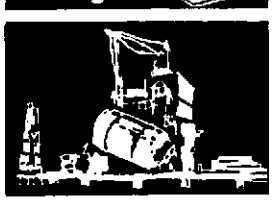
SPACE DIVISION



AUTOMATED BIOWASTE SAMPLING SYSTEM

URINE SUBSYSTEM OPERATING MODEL

FINAL REPORT - PART I

Contract NAS 1-11443

National Aeronautics and Space Administration

Lyndon B. Johnson Spacecraft Center

Houston, Texas 77058

GENERAL ELECTRIC

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Foreward

The Automated Biowaste Sampling System is composed of two major subsystems, the Urine Subsystem and the Solids Subsystem. With the exception of some shared electronics, the two subsystems are physically separate assemblies and may be operated independently or simultaneously as desired. Part I of the final report defines and describes the requirements, equipments, operation and test results for an operating model of the Urine Subsystem. Similar information for the Solids Subsystem Operating Model is contained in Part II of the final report.

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AUTOMATED BIOWASTE SAMPLING SYSTEM

PART I - URINE SUBSYSTEM

1.0 SUMMARY

The Urine Subsystem automatically provides for the collection, volume sensing and sampling of urine from six subjects. Verification of the subsystem design, a scaled-up previous development, was a primary objective of the current effort. This was accomplished thru the detail design, fabrication and verification testing of an operating model of the subsystem.

2.0 BACKGROUND

With the potential of longer and longer manned space flights, it is becoming increasingly imperative that various medical experiments be performed to determine what, if any, effects long duration exposure to zero gravity and a restricted, closed environment will have on the crew. A number of biomedical problems, such as bone demineralization and microbial cross contamination between the crewmen, are well documented in the literature for the one gravity case; however, the extent to which these conditions progress is not known for the actual flight situation.

The SKYLAB program will include a number of biomedical experiments as a start towards understanding the effects of long duration space flight. Included in the SKYLAB equipment is a biowaste sampling capability. This capability, while providing in some measure for the current SKYLAB experiments, has had to allow for a certain amount of compromise due to space and schedule requirements as well as limited capability of presently available equipment. It is intended that the Automated Biowaste Sampling System result in a system of

sufficient flexibility to service medical experiments as presently defined, and also provide for a reasonable range of future medical experiments requirements (involving the sampling of urine, feces, and vomitus) that are not as yet defined.

Items of interest from three SKYLAB medical experiments are presented herein as a starting point for more broadly defined experiment requirements. These three experiments are: M071 Mineral Balance, M072 Bone Densitometry, and M073 Bioassay of Body Fluids. Table 2-1 lists the constituents of interest in urine, feces, and vomitus required for these three experiments. The additional items tabulated are presented to reflect the present status of anticipated future needs. This table is not to be construed to be a complete listing but only as an indication of future requirements.

The Urine Subsystem Operating Model described herein is a further refinement of previous developments by General Electric for NASA-JSC under Contracts NAS 9-1301 and NAS 9-10741. As with the previous development effort, the current operating model provides for the automatic collection, volume sensing and sampling of urine. The current model, moreover, can accommodate six men and the collection of microbiological and chemical samples as well as 24-hour pool samples. The following sections define and describe the Urine Subsystem Operating Model design requirements, equipments, operation and verification test results.

3.0 SUBSYSTEM DEFINITION

3.1 Design Requirements

The contract work statement specifies that the Urine Subsystem Operating Model shall be sized to support a crew of six men, collect and determine

TABLE 2-1 Experiment Requirements

Item	Urine	Feces	Vomitus
Collection Measure	Yes Volume ± 2 %	Yes Wet Mass ± 2 %	Yes Wet Mass ± 2 %
Sample Size Store Return	Yes 120ml/24hr Pool Yes Yes	Yes Total/each Yes Yes	Yes Total/each Yes Yes
Chemicals of Interest (SKYLAB	Sodium Potassium Magnesium Calcium Nitrogen Phosphorus Chlorine Urea Hydroxyproline Creatinine Aldosterone ADH Epinephrine Norepinephrine 17 Hydroxy-corticosteroids	Potassium Magnesium Calcium Nitrogen Phosphorus Chromium	Potassium Magnesium Calcium Nitrogen Phosphorus Chromium
Additional Items of Interest that may be required at some future time	pH Osmalality Electrolytes Angio Tension Hydro Cortisone Renin Amino Acids Microbiology Others	Sodium Chlorides Proteins Carbohydrates Cellulose Fatty Acids Microbiology Anaerobes Others	Sodium Chlorides Proteins Carbohydrates Cellulose Fatty Acids Microbiology Anaerobes Others

the volume of individual micturtions, isolate appropriate sizes and numbers of samples for post flight or on-board analyses, and dispose of excess urine to the spacecraft life support system. In addition, the subsystem must maintain itself in a clean condition between uses (i.e., insure less than 1% cross-contamination between individual voids), provide for odor and contamination control, and provide for positive identification of each of the samples taken as to biowaste event (crewman ID, date, time). The operating model shall also be automated as practical to minimize crew time and sample handling. Although optimization for minimum weight, power and size is not required, the operating model must be configured to provide both a functional and attractive appearance representative of a possible flight design.

Based on the work statement design requirements and the general system concept as represented by the previous contract effort, an operating model design requirements specification was prepared (enclosed herewith as Appendix 7.1). This design specification, which defines both primary and secondary performance requirements, was used as the design control document.

3.2 Description and Operation

3.2.1 Description

Figure 3.2-1 is a photograph of the assembled subsystem; Figure 3.2-2 illustrates the subsystem block diagram. The urinal, phase separator, blower and filter provide the urine collection capability. The urinal, a hand held funnel shaped receptacle connected by a flexible hose to the phase separator, also encloses the microbiological sample container. The blower provides a source of transport air for conveying the urine into the phase separator. The filter prevents odor and bacteria from being exhausted to the ambient environment via the transport air stream. The centrifugal phase separator

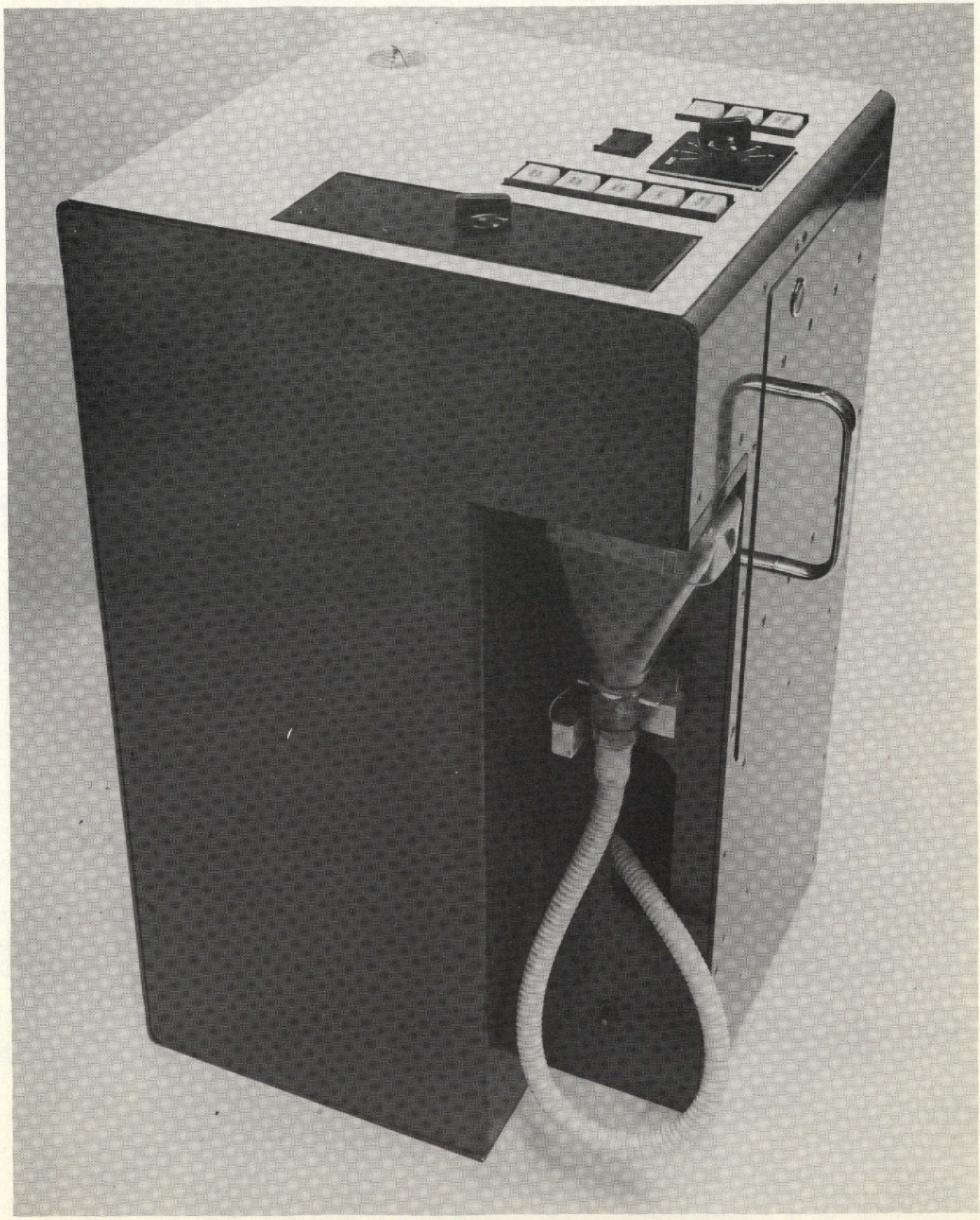


Figure 3.2-1. Urine Subsystem Operating Model

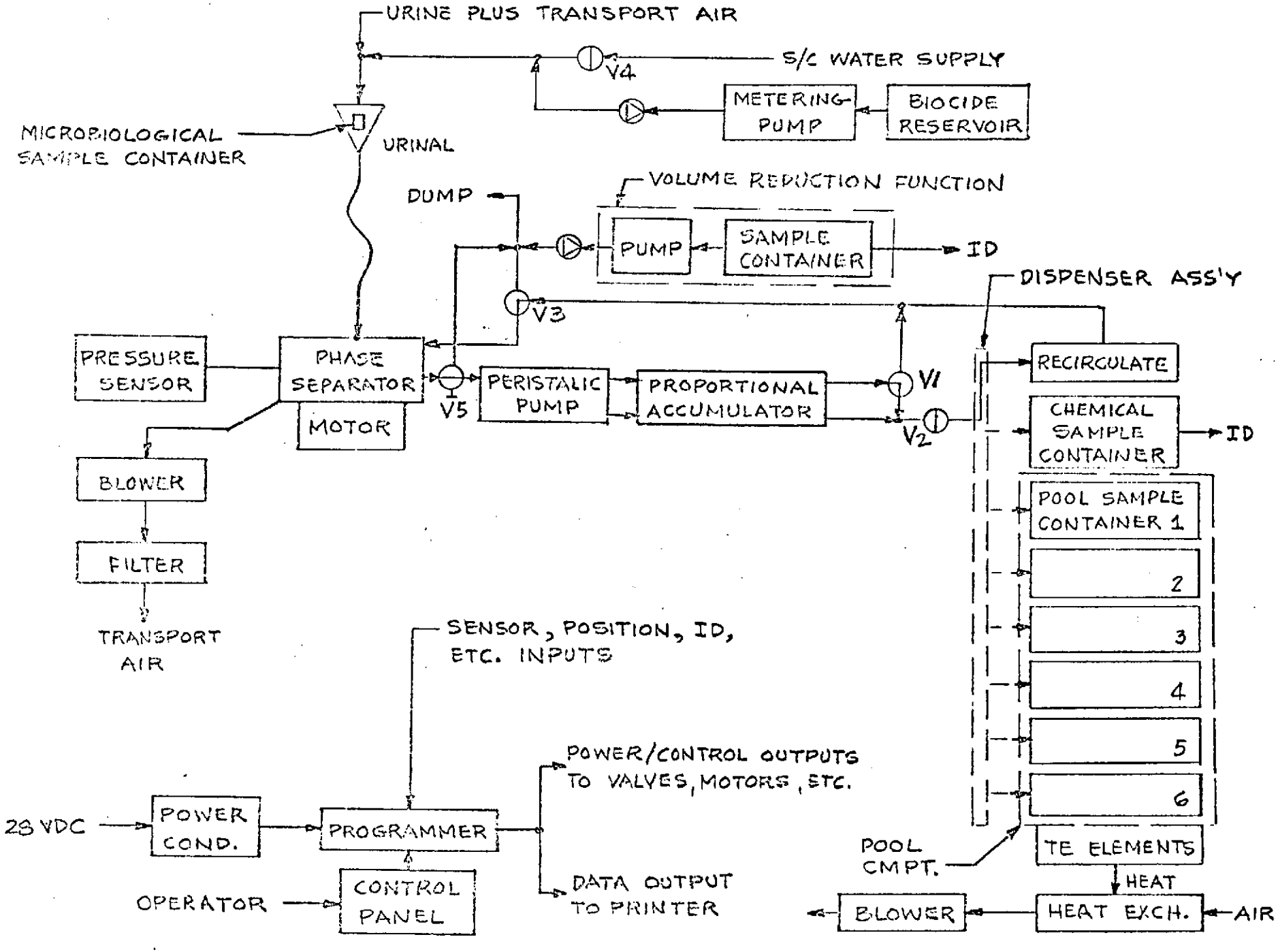


FIGURE 3.2-2. ABSS URINE SUBSYSTEM OPERATING MODEL BLOCK DIAGRAM

both stores the incoming urine, provides a mixing action so that the urine is homogenous and separates the transport air from the liquid urine. The peristaltic pump and accumulator provide both volume measurement and sample isolation functions. The accumulator has two chambers on a common shaft. The larger chamber has a nominal volume of 25 ml, the smaller, 2.5 ml. The output of the smaller chamber may be directed to the 24-hour sample container to provide a representative 10% sample of the total 24-hour voiding and/or directed to a chemical sample container. The dual tube peristaltic pump is used to fill the accumulator. The pump also prevents flow back to the phase separator when the accumulator discharges. The 24-hour pool sample containers, flexible evacuated plastic bags, are located in a refrigerated pool compartment (the side access door in Figure 3.2-1). The chemical sample container is located on top of this compartment. The pressure sensor is used to acquire control data for the programmer to terminate volume measurement and sampling and start or by-pass (for micturition volumes less than 50 ml) the volume measurement and sampling portion of the cycle. The total volume for each micturition, which exceeded the minimum size of 50 ml, is recorded on an external printer along with biowaste event data. The programmer includes the pressure sensor signal conditioner, phase separator motor servo speed control, and control logic for controlling the system operating sequence.

The subsystem is designed to be operated with or independently of the Solids Subsystem. However, the operator controls for both subsystems are combined into one panel arrangement located on the top surface of the Urine Subsystem structure. Some electronic components are also shared between the two subsystems.

3.2.2 Operation

Figure 3.2-3 illustrates the three subsystem operating sequences. Note that power is ON continously (to provide time reference and to operate the pool compartment thermoelectric cooling capability. However, each operating sequence must be initiated by the user.

3.2.2.1 Sampling Sequence

The function of the sampling sequence is to collect, sample and measure each micturition. Three separate sampling containers are provided, i.e., microbiological, chemical and 24-hour pool. If used, a fresh microbiological and chemical sample container is installed for each micturition. The 24-hour pool sample container is replaced on a 24-hour cycle. The sampling sequence is composed of several operating phases as follows.

Supplemental information on system operation is also available in the Operating Model Requirements Specification (Section 3.1.1.2.4 of Appendix 7.1) and the Operating Instructions (Appendix 7.3).

3.2.2.1.1 Collection

The function of this phase is to collect and store the incoming urine in the phase separator. To start this phase the user actuates the "START" switch. All subsystem elements are now operational. The user then removes the urinal and urinates into the urinal. Either a standing or sitting position may be used. If seated, the urinal must be raised to the equivalent of that required for the standing position to assure that urine is not trapped in the hose (not required for operation in zero gravity). If in place, a small portion of the urine is trapped in the microbiological sample container located in the urinal. The urine is conveyed from the urinal, through the urinal hose into the phase separator by the transport air flow. This air flow is

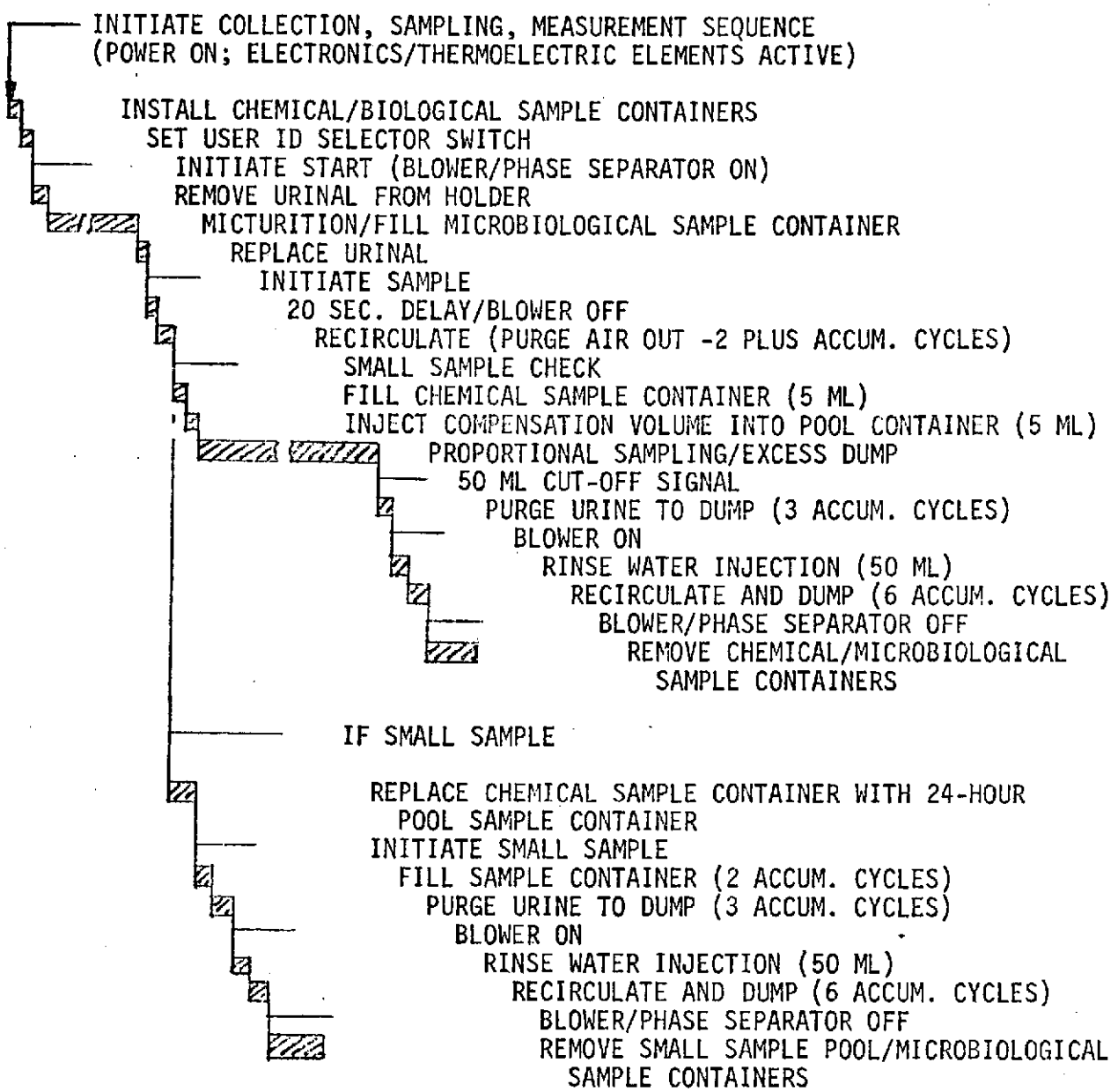


FIGURE 3.2-3(a). SAMPLING SEQUENCE (NOT TO SCALE)

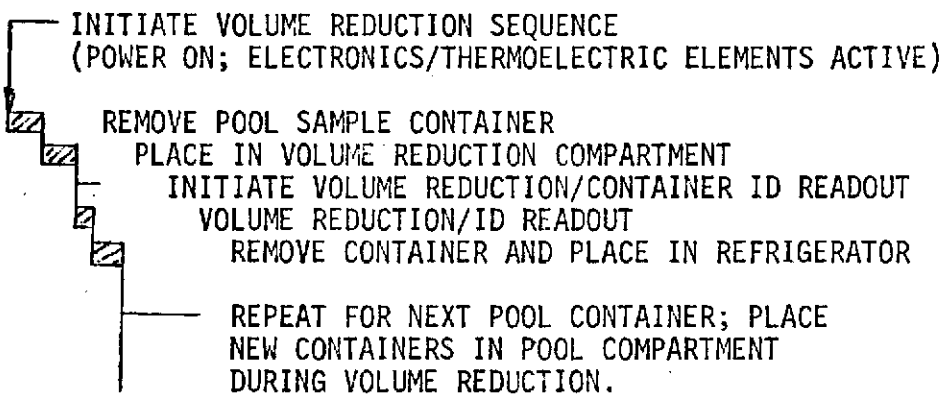
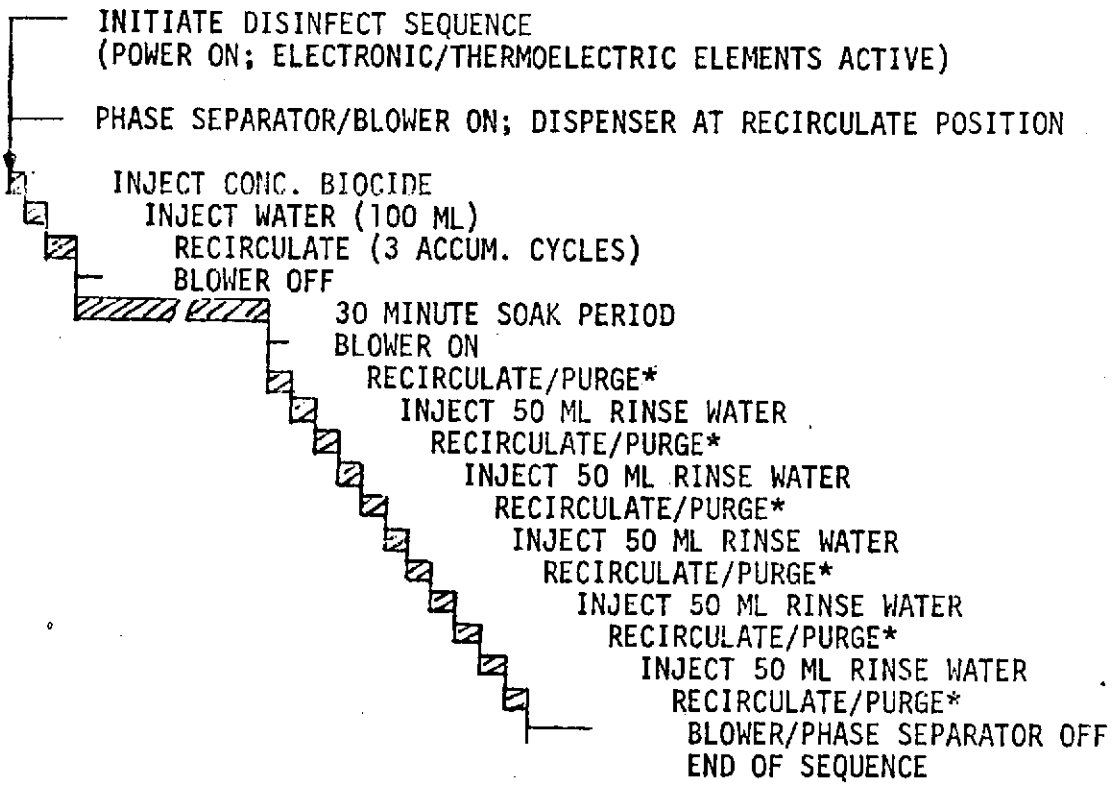


FIGURE 3.2-3(b). VOLUME REDUCTION SEQUENCE (NOT TO SCALE)



* 3 RECIRCULATE FOLLOWED BY 3 DUMP CYCLES OF THE ACCUMULATOR

FIGURE 3.2-3(c). DISINFECT SEQUENCE (NOT TO SCALE)

generated by the blower, the transport air being returned to ambient via the odor and bacteria control filter.

Due to the centrifugal action of the phase separator, the incoming urine forms an annular liquid vortex constrained in position by the phase separator housing. Trapped air bubbles migrate to the free inner surface of the vortex and are removed by the transport air flow.

3.2.2.1.2 Air Purge, Measure and Sample

When micturition is complete, the user replaces the urinal and actuates the "SAMPLE" switch. This deactivates the blower and starts the pump to purge air from the lines, valves and accumulator. After air purge, the pressure switch is interrogated to determine if the micturition is large enough to measure and to provide a 24-hour pool sample input. If the pressure switch indicates less than 50 ml of urine in the phase separator, a SMALL SAMPLE condition exists and the SMALL SAMPLE switch indicator light flashes and further action inhibited until manual restart by the user (See 3.2.2.3 Below).

Assuming a micturition volume greater than 50 ml, the accumulator fills, the dispenser moves to the chemical sample container position and 5 ml of urine is discharged from the accumulator into the chemical sample container. The dispenser then moves to the appropriate 24-hour pool container (as directed by the user ID selection switch). After a compensation volume of 3.5 ml is discharged into the 24-hour pool container (10% of the 35 ml remaining in the phase separator at sampling cut-off), the pump, accumulator and valves V1, V2 and V3 are positioned for proportional sampling, i.e., 10% to the 24-hour pool container, 90% to dump. At the end of each fill stroke of the accumulator, the pump automatically stops, the valves are repositioned, and the accumulator discharges (via return spring action). During discharge the

pump acts like a valve, preventing flow back to the phase separator. Alternate fill/discharge cycles are repeated until the liquid level in the phase separator reaches 35 ml as determined by the pressure switch output, the phase is terminated.

3.2.2.1.3 Small Sample

If a SMALL SAMPLE condition is indicated, the chemical sample container is removed and a 24-hour pool container substituted. The user that actuates the SMALL SAMPLE switch which moves the dispenser to the chemical sample container position. The pump and accumulator action then complete two fill/-discharge cycles which effectively empties the phase separator (less a small residual) into the sample container. The container number, user ID and mission time are recorded on the external printer.

3.2.2.1.4 Purge

With the dispenser in the recirculate position, three alternate accumulator fill/discharge cycles are completed to purge all but the residual urine from the subsystem. During purge, the total urine volume plus user ID and mission time is recorded on the external printer.

3.2.2.1.5 Water Rinse

At the end of purge, the blower is reactivated and 50 ml of water from the spacecraft supply is injected into the subsystem via the urinal. This rinse water is recirculated and then dumped to "clean" the subsystem for the next user. At the end of the water rinse phase, the subsystem automatically reverts to the pre-START condition.

3.2.2.2 Volume Reduction Sequence

At 24-hour intervals, the 24-hour pool sample containers are replaced. Since the urine volume in each pool container may be as large as 400 ml (10% of 4000 ml), this volume must be reduced to 110 ml before placing the sample container in storage. This is accomplished by the volume reduction sequence. Each pool container in turn is manually inserted into the volume reduction assembly volume and the access door closed. The VOLUME REDUCTION switch is then actuated by the operator. This causes the volume in the sample container to automatically be reduced to 110 ml, the excess being pumped to the dump outlet. Simultaneously, the container number, corresponding user ID and mission time are recorded on the external printer.

3.2.2.3 Disinfect Sequence

At approximately 24-hour intervals or as required, the disinfect sequence may be initiated by the operator by actuating the DISINFECT switch. This activates the blower and phase separator. With the dispenser in the recirculate position, concentrated biocide (10 ml) and rinse water (100 ml) are injected into the subsystem via the urinal and recirculated. After a 30 minute delay period (to allow sufficient time for maximum microorganism kill efficiency), alternate fill/discharge cycles of the accumulator are used to purge the biocide solution to the dump outlet. Mission time is recorded on the external printer at start of the sequence.

3.2.2.4 Emergency Operation

Manual valve V5 may be used to bypass sampling and measurement functions in case of equipment malfunctions.

3.2.3 Interlocks

The subsystem contains a number of interlock features which prevent subsystem operation under abnormal conditions. Thus, if the phase separator has not reached operating rpm within one second after actuation of the START switch, the START switch indicator light goes to a flashing condition (to alert the user) and further subsystem operation is inhibited. Similarily if the urinal is not in its stowed position, the disinfect sequence will be inhibited. These and other interlock features are noted in Appendix 7.1, Section 3.1.1.2.4 and Appendix 7.3.

4.0 EQUIPMENT DESCRIPTION

The urine subsystem is physically divided into three main assemblies:

The fluid recirculation assembly

The fluid sampling assembly

The structure and electronics assembly

The fluid recirculation assembly is shown in Figure 4.0-1 (front view) and 4.0-2 (back view). It includes in addition to the phase separator all the components required for the air recirculation, i.e. blower and filter, the fluid recirculation, i.e. pump and accumulator with valves and the emergency dump valve. The assembly is mounted on a plate and provided with electrical connectors for ease of removal.

The fluid sampling assembly consists of the pooling compartment and the fluid dispensing mechanism. The structure and electronics assembly includes all the other components such as the biocide dispenser, urinal installation, the volume reduction compartment, etc. These units are directly wired and not removable with the same ease as the fluid recirculation or the dispenser assemblies.

The fluid sampling assembly and the structure and electronics assembly are shown in Figures 4.0-3 and 4.0-4.

4.1 Urinal

The urinal is illustrated in Figure 4.1-1. The design is a modification of the typical conical collection device on present spacecraft. The unit is easily detachable from the assembly and can be used by either male or female astronaut independently or in conjunction with the solids subsystem.

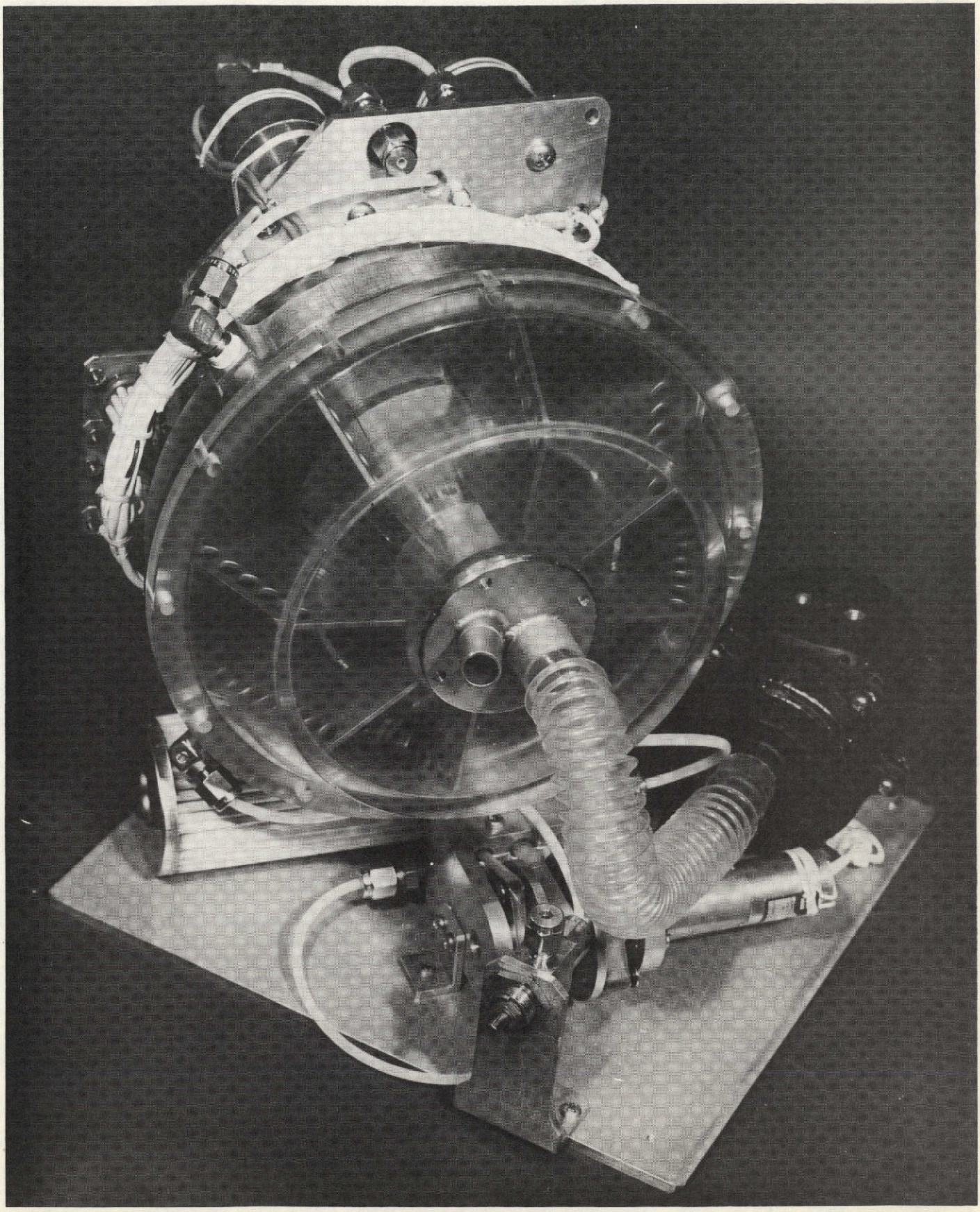


Figure 4.0-1. Fluid Recirculation Assembly - Front View

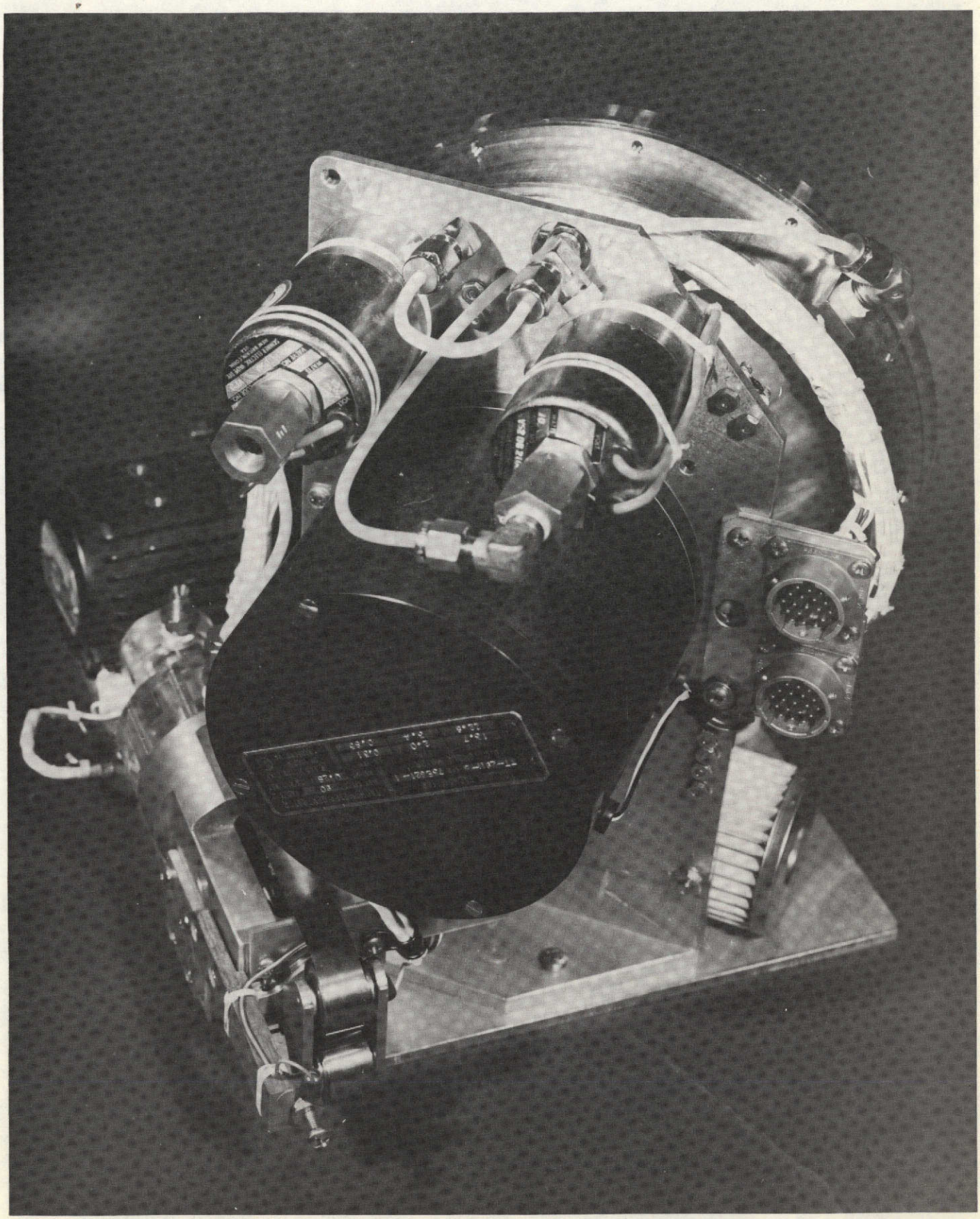


Figure 4.0-2. Fluid Recirculation Assembly - Back View

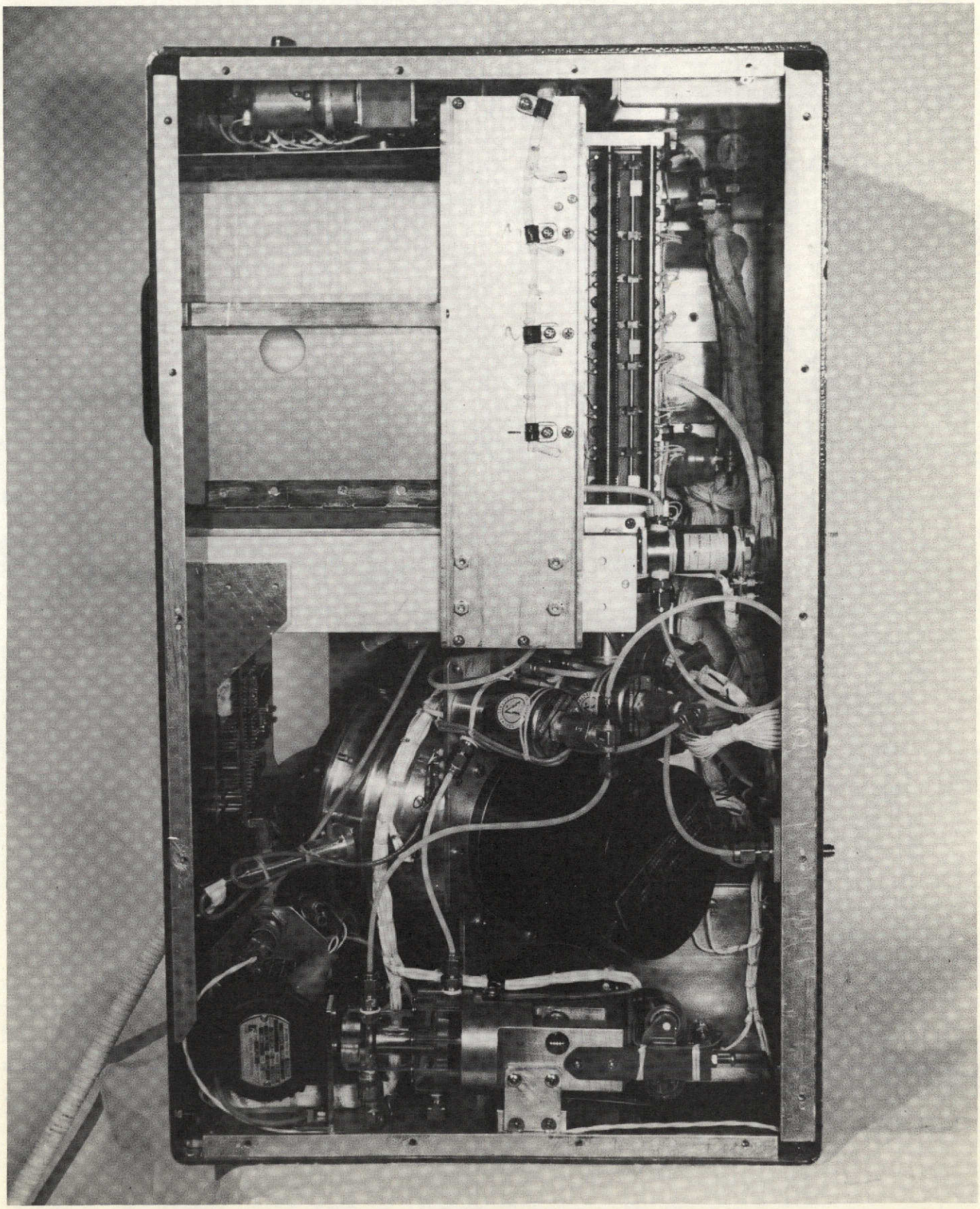


Figure 4.0-3. Side View With Fluid Sampling Assembly

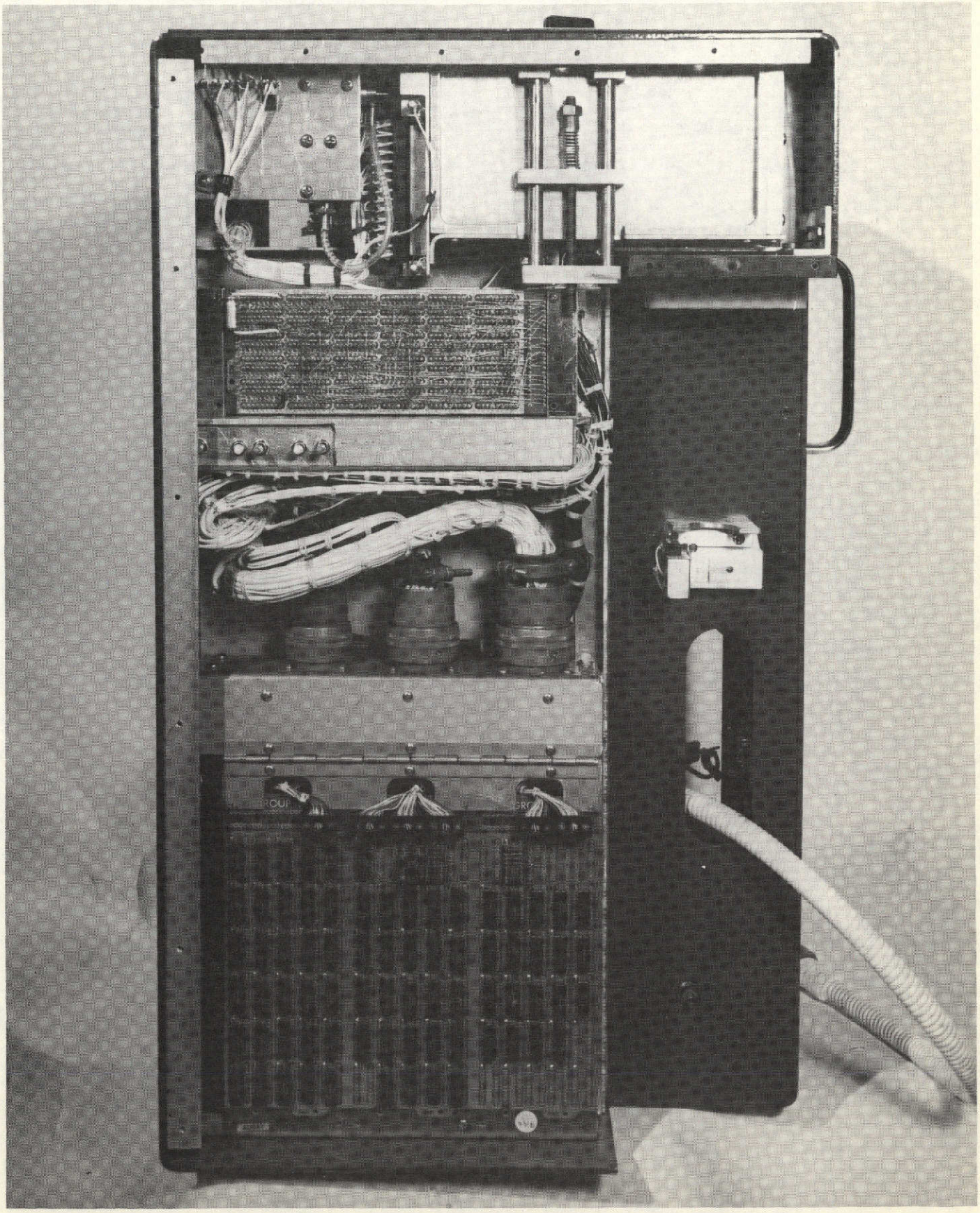


Figure 4.0-4. Side View Structure and Electronics Assembly

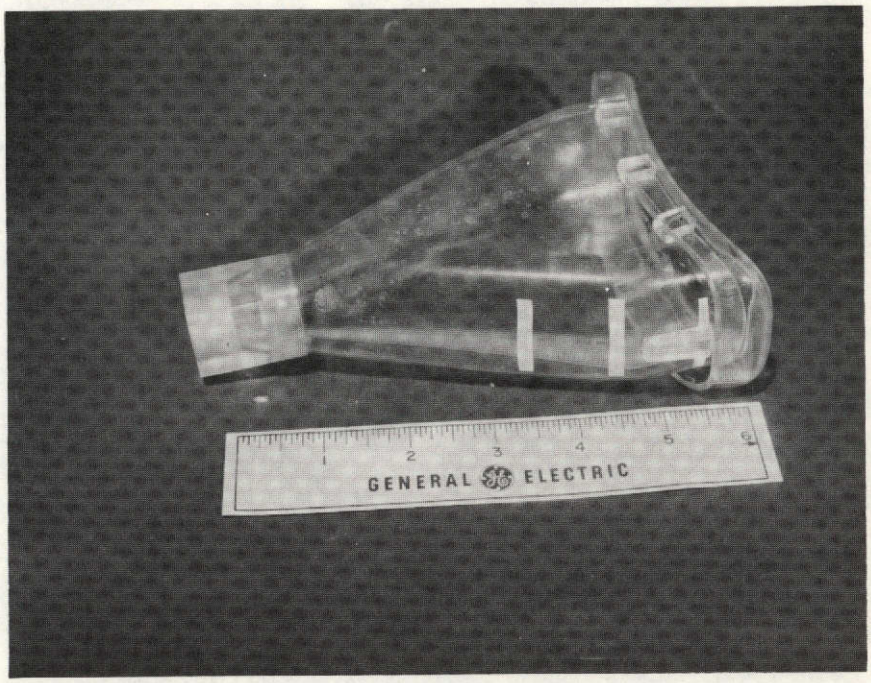


Figure 4-1.1. Urinal

The urinal consists of two basic parts: a funnel and a skirt. The funnel is the part that receives the urine. It has a very narrow cone angle and very smooth surface in order to effect the transfer of liquid into the hose and the phase separator, with a minimum of splash. The receiving end of the funnel has been flattened and fitted with a skirt which allows a limited amount of contact by the femate user without blocking the air flow required to move the liquid stream in zero gravity conditions.

The connecting hose is made of white silicone rubber reinforced with stainless steel wire. The urinal is held in place by a clip below the flush assembly which dispenses water and biocide as required.

The urinal is also used for the direct collection of the sample of microbiological analysis. The sampler is installed directly into the urinal. See paragraph 4.6 for more details.

4.2 Phase Separator

The design of the phase separator shown in Figure 4.2-1 is typical of previous GE designs with several improvements and refinements.

The phase separator utilizes the mass density difference between the transport air and urine for centrifugal phase separation. It is a dynamic system in which the urine is contained in an annular envelope vortex generated at the outer diameter of the housing by a rotating impeller while the air is returned through a secondary centrifugal separator at the inlet of the return air plenum.

The assembly consists of four major elements:

1. An upper housing made of Plexiglas and containing the air return plenum.

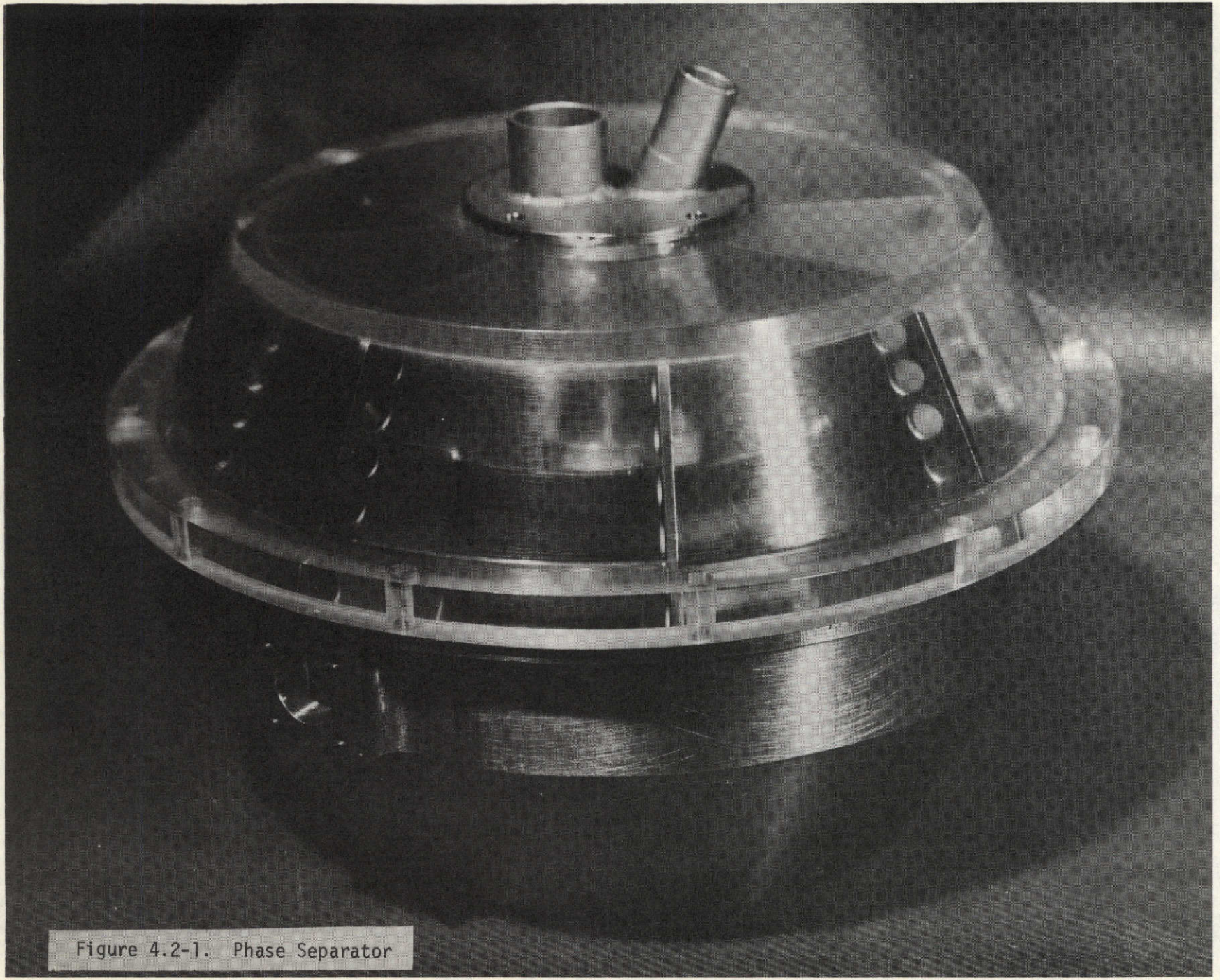


Figure 4.2-1. Phase Separator

2. A lower housing made from type 316 stainless steel, containing the bearing housing for the impeller assembly and motor coupling.

3. An impeller assembly also made from type 316 stainless steel with debris filter.

4. The motor-tachometer used to drive and control the speed of the impeller assembly.

The upper housing was made of Plexiglas to permit visual inspection of the internal operation of the assembly. Both the inlet and outlet lines are part of the assembly; the two are separated by an "O" ring between the inlet tube O.D. and the impeller assembly so that the air-urine mixture has to travel through the impeller assembly before it can return to the air return plenum which surrounds and is concentric with the inlet line.

The lower housing contains, in addition to the bearing housing, the return line from the recirculation loop, the inlet to the pump, and the pressure transducer.

The impeller assembly consists of eight blades nested at the periphery of two parallel disks one of which is used for attachment to the motor, the other to connect to the inlet line. The disks form a gradually expanding throat contributing as much momentum as possible to the mass of the urine passing through so that the urine will impinge into the annular vortex rather than follow the air return path. The wide end of the throat is enclosed with a wire mesh stainless steel screen made of 20 mesh ,016 dia. wire. The purpose of the screen is to entrap any debris which may be carried through the urinal into the phase separator.

The impeller assembly has an auxiliary set of blades which further assures the interception and rejection by centrifugal action of any liquid droplets which may pass through and beyond the perforated annular section that separates the liquid vortex area from the air return plenum.

The edges of the blade assembly have been perforated with a series of holes in order to minimize the unbalance of liquid volume contained between each pair of rotating blades thus obtaining a relatively high degree of stability at either high or low speed.

The motor is a special torque motor-tachometer generator combination made by the Inland Motor Corporation of Radford, Virginia, and is identified as part No. TT-2911.

The motor is capable of a torque of 90 in-oz at 400 RPM. The addition of the tachometer generator on the same shaft of the torque motor provides an output voltage which is proportional to the speed. The voltage output is fed into a servo amplifier which in turn controls the input voltage (and speed) to within $\pm$.1% from no load to full load.

The design of the phase separator is basically the same as used on previous equipment such as the Urine Sampling and Collection System delivered to NASA under contract NAS 9-10741 except for some detail refinements and a significant reduction in weight as expected for flight type hardware.

4.3 Blower/Filter

The blower and the filter are commercial units fully described in the manufacturer literature attached in Appendix 7.4.

The blower is made by Rotron Manufacturing, Woodstock, New York, and is identified by part number RRFP-RS-201 series 1557 AF. It is powered through a DC to AC inverter which is also provided by the same manufacturer under part number BC 333 Type 256.

The blower is capable of flowing 2 CFM of air against a 10" W.G. back pressure.

The filter is a junior size commercial Petrosorb Ultipor .9 Cartridge made by Pall Aircraft Porous Media, Glen Clve, Long Island, New York. It is identified by part number MCS4463UP. It has a 1.6 ft^2 of surface filter area and has a removal rating of 100 percent for particles size up to .08 micron and 98 percent for particles size up to .008 micron.

4.4 Pump/Accumulator

The pump and the accumulator with the appropriate valves are the main components used to recirculate, pressurize, purge, measure and divide the flow into the required 10/1 nominal ratio.

4.4.1 The Dual Pump

The pump is a positive displacement, self priming, non-clogging device commonly referred to as a "peristalic" or "roller" pump. It is illustrated in Figure 4.4.1-1.

Pumping action is obtained by the progressive rolling deformation of the flexible tubes of silicone rubber material stretched over a set of free turning rollers. The pumping mechanism is the same as that of the 30-Day Biosatellite unit or the previous USVMS and USCS programs.

Few further changes have been made either to simplify or to adapt the unit to the present program:

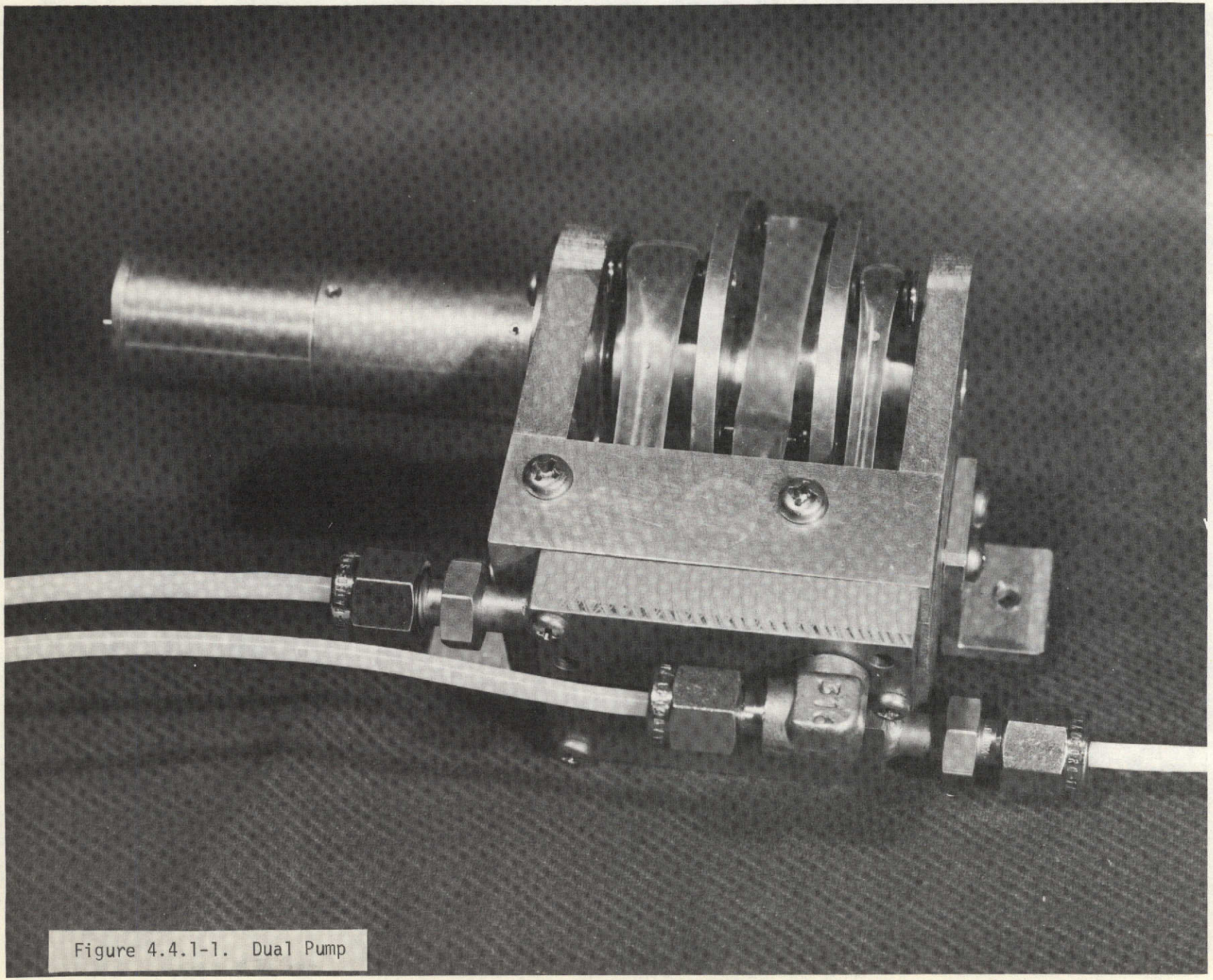


Figure 4.4.1-1. Dual Pump

1. A total of three pump tubes are used. The main flow is provided by two tubes in parallel identified as Cat. #01-00-05. The proportional flow which is the nominal 1/10 of the total is provided by one tube identified as Cat. #01-99-0019. The tubes are made by the Extracorporial Medical Specialties, Mt. Laurel, N.J.

2. The inlet to the pump has been manifolded so that one fitting connects all three tubes. The output is also a one-piece design with one fitting for the low flow and a second fitting for the high flow.

3. The rotor assembly and motor attachment have been improved.

The pump is driven by Globe Motor part #43A104-2 and is capable of pumping fluid at a rate in excess of 200 cc's/min against a back pressure of approximately 6 psig.

4.4.2 The Dual Accumulator

The main function of the accumulator is to measure the dual flow from the pump with an accuracy of better than 1 percent.

The unit has two pumping or collection chambers with a sectional area ratio of 10:1 served by a common stepped down piston.

The two chambers are separated by an "O" ring. Both chambers are contained in a Plexiglas cap which permits visual inspection of the status of the assembly.

The filling pressure of the accumulator is provided by the pump described in paragraph 4.4.1. The discharge pressure is provided by a set of negator springs attached to the end of the piston. The piston shaft is also used to perform

the most significant control functions in the metering of the liquid flowing through the system in addition to mechanically balancing and aligning the piston with respect to the chambers. Part of the shaft has been turned into a cylindrical rack to convert the lunar motion into rotational motion through a pinion as can be seen in figure 4.4.2-1. The pinion is attached to the disk with a number of holes which are detected by a photoelectric sensor thus producing a signal output for every 0.25 cc of liquid discharged. The sensor is made by Texas Instruments and is identified as part number TIL138. The end of the shaft is also fitted with a "common" contact to provide an "empty" or "full" electrical signal at either end of the stroke. The "full" contact is adjustable thus allowing the control of the total amount of fluid discharged per stroke.

4.5 Pressure Sensor

A Setra-Systems, Inc., Model 237 pressure sensor was selected to provide the sampling cut-off signal (35 ml remaining in the phase separator) and the small sample signal (sample below 50 ml). The sensor consists of a thin stretched diaphragm which acts as the moveable plate of a variable capacitor. Built-in electronics converts the capacitance changes due to pressure variations into a high level DC output signal. The selected sensor has a full-scale pressure range of 0 to 0.2 psia. Additional information is noted in Appendix 7.4.

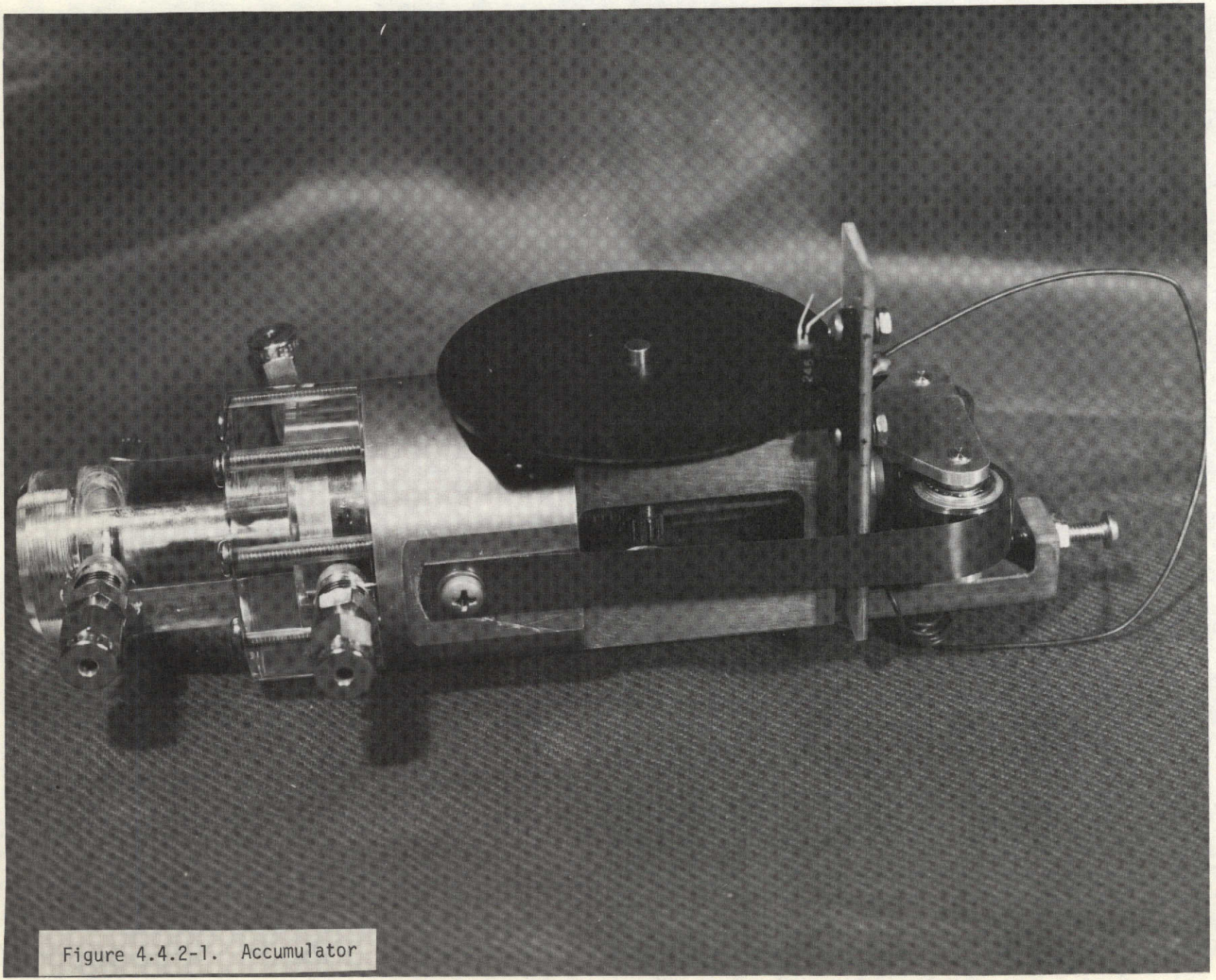


Figure 4.4.2-1. Accumulator

4.6 Sample Containers

The ABSS requires collection containers for the following analyses of samples:

1. Microbiological sample
2. Real time sample (chemical sample)
3. Pool sample
4. Total volume emergency sample.

4.6.1 Microbiological Sampler

The sample for microbiological analysis is collected directly in the urinal to minimize the chance of cross contamination. The device for collecting such sample is composed of two basic parts: the container and the collector assembly. The container consists of a cylindrical housing and a cap. In addition to the basic function of hermetically enclosing the collector assembly prior to and after use, the container is also used as a tool to install the collector assembly in the urinal and to remove the same without hand contact.

The collector assembly consists of a wick and a shield. The wick is designed to retain approximately 2 cc's of urine. The shield is designed to prevent contamination by droplets splashing from the walls of the urinal. The lower end of the wick and shield are held by a Teflon plug with an X-cross section to minimize flow restriction. The container and collector assembly are shown in Figure 4.6.1-1. The collector has a 360° groove with two sets of axial slots 180° apart; the cap has a set of hooked wires, and the container has a set of pins or bayonets near the open end. The device is used as follows:

1. Storage Configuration: The assembly is stored after sterilization with identification by serial number. Sterilization is maintained by an external tape seal holding the cap to the container. The cap hooks are engaged to the plug on the collector assembly.

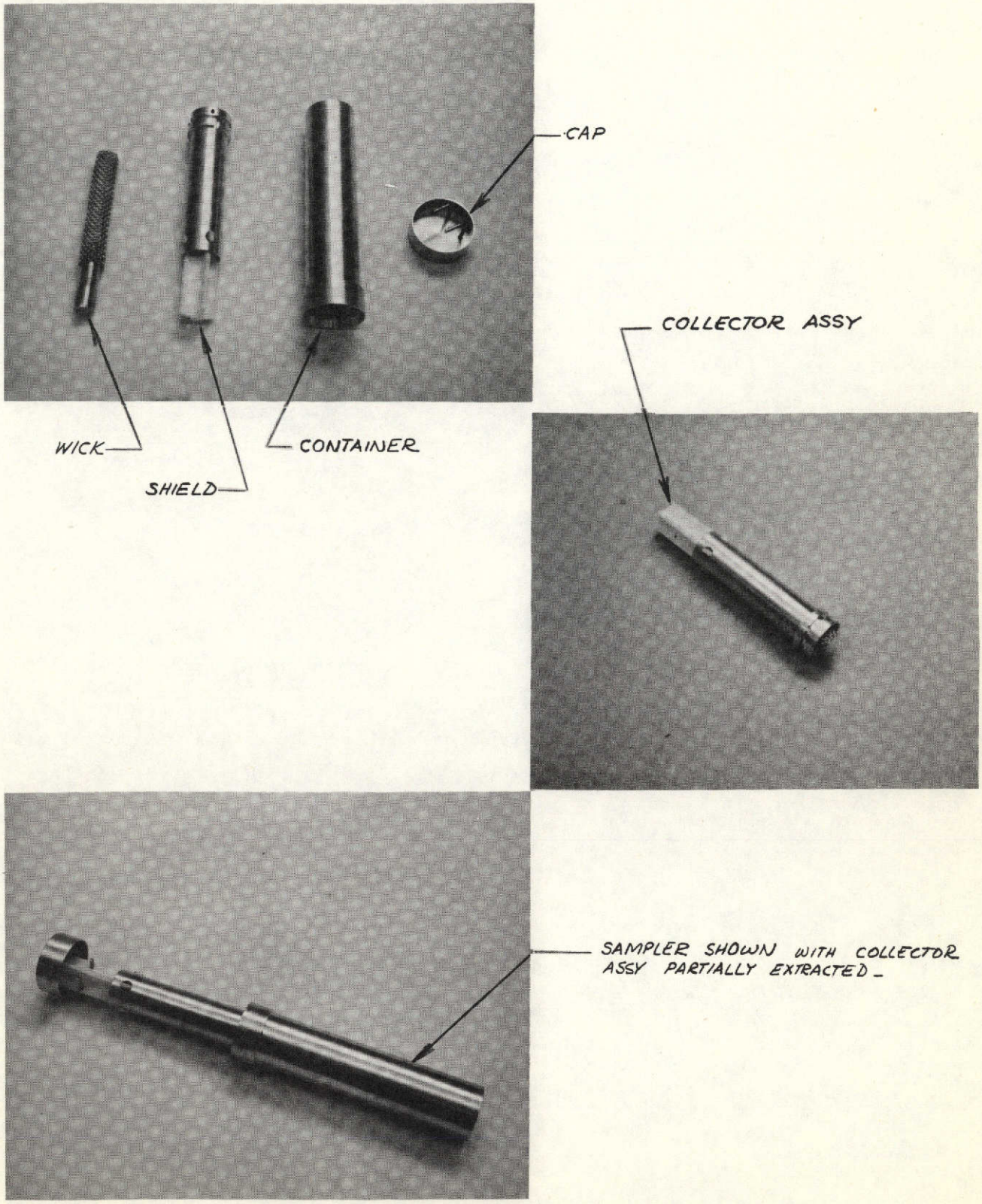


Figure 4.6.1-1. Microbiological Sampler

2. Preparation for Use: The tape seal is broken and the cover is pulled away from the container. The two hooked wires in the cap hold and pull the sampler out until the shoulder on the sampler stops against the bayonet on the container. The sampler is then rotated by means of the cap so that the bayonets pass through the lower axial slots and stop against the upper shoulder. A slight additional rotation (less than 90°) either left or right locks the sampler to the container in the axial direction only. In this position, the sampler is ready for installation; the container is used as a tool to install the sampler in the urinal.

3. Installation: The sampler is installed and held in the urinal by a light friction fit. The container is then rotated to clear the axial slot in the upper shoulder and disengaged.

4. Use: During urination, some of the urine will impinge on the wick, some will bypass it. With a minimum of effort from the part of the user, the wick can be made to retain a good representative sample of most of the total fluid.

5. Removal: The removal procedure is the opposite of the installation sequence. The container is engaged to the sampler and the sampler is pulled out. The cap is engaged to the plug in the sampler and the sampler is then pushed back into the container and resealed.

The container assembly should be numbered with serial numbers from 1 to 999 and paired with the real time sampler for the purpose of recording all the pertinent data.

4.6.2 Real Time (Chemical) Sampler

The collection device used for the real time chemical sample is shown in Figure 4.6.2.1. The device consists of three basic parts: the system, the container, and the identification tag.

The system consists of a "duck bill" valve developed for the Skylab program and rated for thousands of penetrations without deterioration. The duck bill housing has been closed at the outlet end and fitted with a tube.

The container is a small Teflon bag sized for the collection of 5 ml and connected to the system through a 3/32 dia tube. The tag is used to hold, install, identify, and remove the sampler assembly. Identification is accomplished by the holes in the tag which are read in binary code by an assembly of twelve light detectors when the sampler is installed.

4.6.3 Pool Sampler

The pool sampler, as illustrated in Figure 4.6.2-1, is basically the same as the real time sampler except for the type and size of container which needs to be capable of collecting as much as 400 ml. The container is approximately 7 x 2 x 2 inches in size and made in collapsible, single fold, accordion shape. The containers are also designed to be made from .003 inch Teflon sheet rigidized by two captive 7 x 2 inch end plates. However, for the demonstration model, latex rubber was substituted for the Teflon.

Also the tag on the pool sample require three additional holes which are covered with a thin foil. The foil is permanently punched in binary code with the users ID when the tags are installed thus avoiding the possibilities of later confusion since the read-out is done after removal and transfer to the volume reduction compartment.

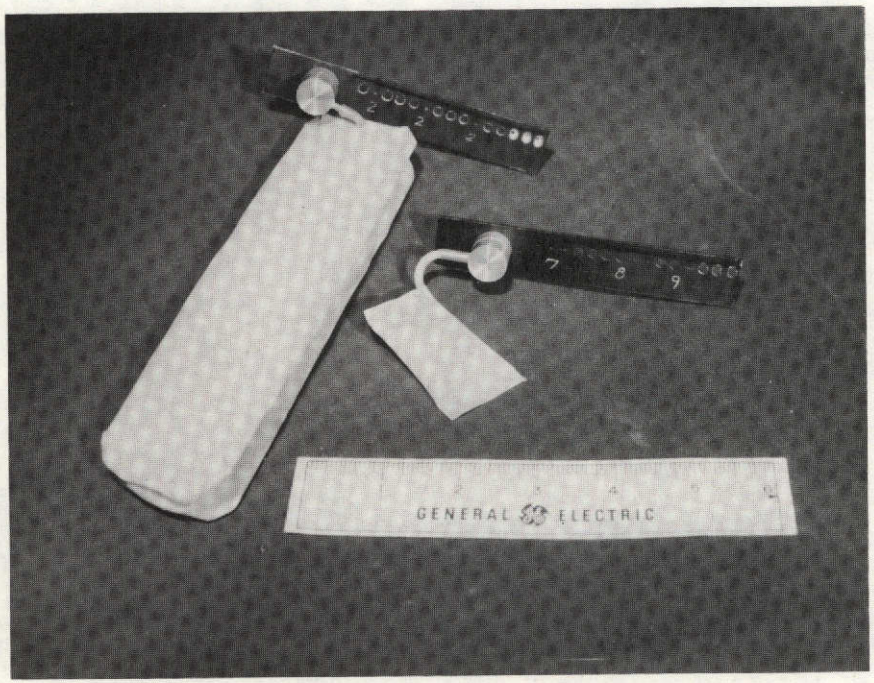


Figure 4.6.2-1. Real Time and Pool Sample Containers

4.6.4 Total Volume Emergency Sampler

This collection device is to be used only in emergencies when the total micturition is below 50 ml. It is to be used in the same manner as the real time sampler, therefore, the same real time sample container could be used if the volume were increased to 50 ml capacity. Also the pool sample container could be used. However, for the purpose of the prototype demonstration unit, a 50 ml container was made similar to the real time sampler except for the capacity of the container.

4.7 Dispenser Assembly

The dispenser assembly is partially visible in Figure 4.0-3. It is shown in more details in Figure 4.7-1 which is part of the assembly drawing. The dispenser assembly is used to perform two mechanical functions:

1. To move the fluid dispensing needle along a vertical axis to a position of alignment with any of eight possible positions, i.e., the return septum, six pooling compartment septa, and the real time chemical sample septum.

2. To drive the dispensing needle into the selected septum and out of the septum after discharging the required amount of fluid.

The dispenser assembly consists of the following basic parts:

1. The frame with parallel guide rods and vertical drive screw.
2. The vertical drive motor, globe part #168A225-2.
3. The moving carriage
4. The needle drive assembly mounted on the carriage.
5. The position sensors, Texas Instrument #TIL138, which have exactly the same spacing as the septa on the pooling compartment.

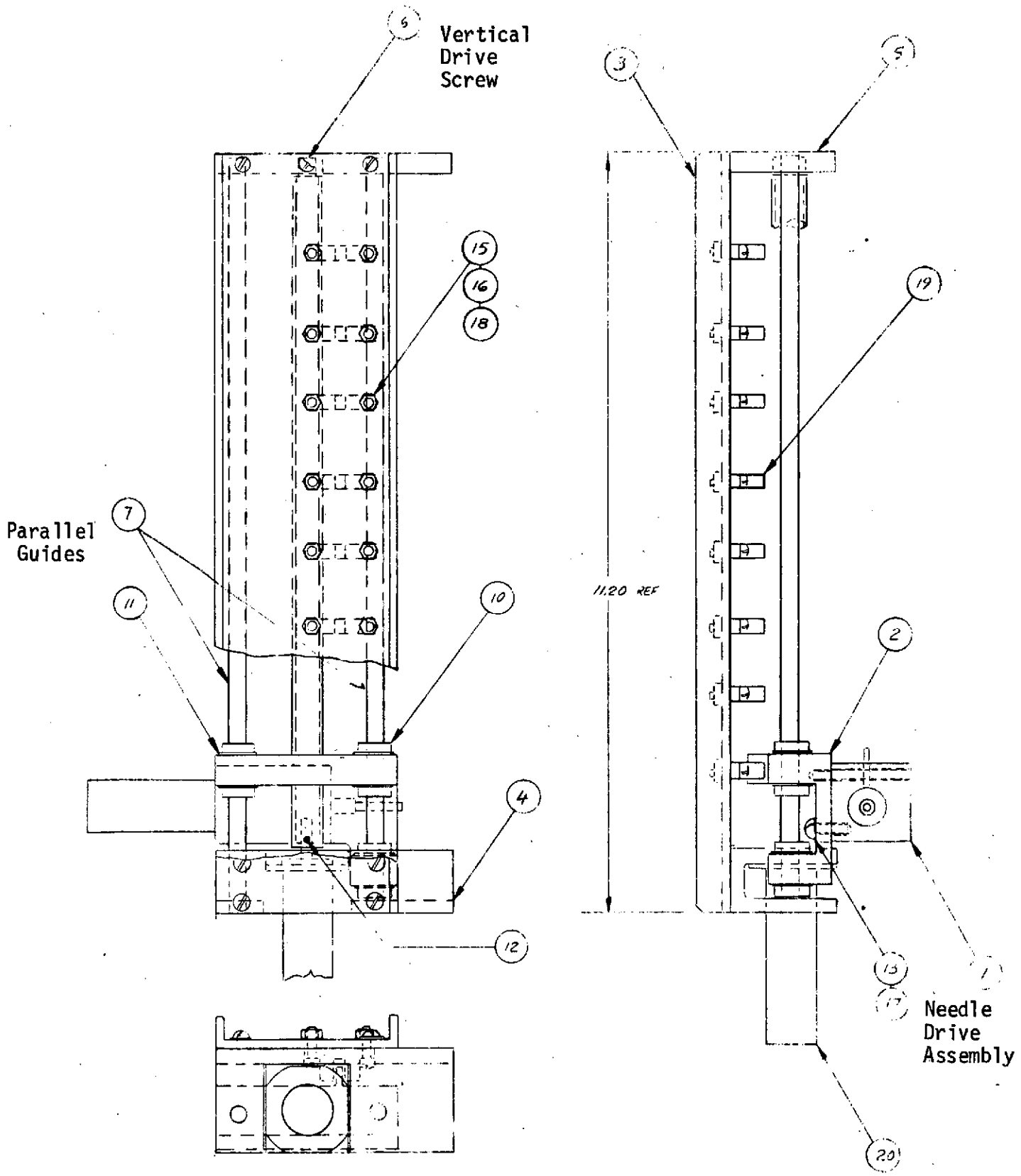


Figure 4.7-1. Dispenser Assembly

The needle drive assembly consists of a drive motor, same as the vertical drive motor, coupled to a screw which moves the injection needle a sufficient amount to penetrate the septa and discharge the fluid. The length of travel is controlled by limit switches. Mounted right next to the needle is the V2 valve. This minimizes the length of free line between the needle and the valve and thus avoids possible spillage as the carriage moves from one extreme position to the other.

The dispenser assembly is wired as a complete unit with separate connector and is mounted to the pooling compartment forming the fluid sampling assembly.

4.8 Biocide and Flush Water Assembly

The components of the biocide and flush water assembly are shown in Figure 4.8-1. Flush water is obtained by energizing the normally closed valve, part no. B2DA1026. Water is released through the nozzles of the Teflon plenum which is installed immediately above the urinal. The nozzles are aimed slightly outward so as to flush the wall of the urinal as close to the inlet end as possible. The biocide portion of the assembly consists of the pump, the reservoir, and a check valve.

The check valve is required to prevent the flush water from getting into the biocide reservoir.

The pump, model 8034 made by the Micropump Corporation of Conford, California, is magnetically coupled and has a non-corrosive polypropylene body. The reservoir is made from a standard 600 ml blood pack made by the Fenwal Laboratories, Morton Grove, Illinois. The reservoir is filled with 300 ml of 30% Betadine solution. The effectiveness of Betadine as a disinfectant is discussed in Appendix 7.5.

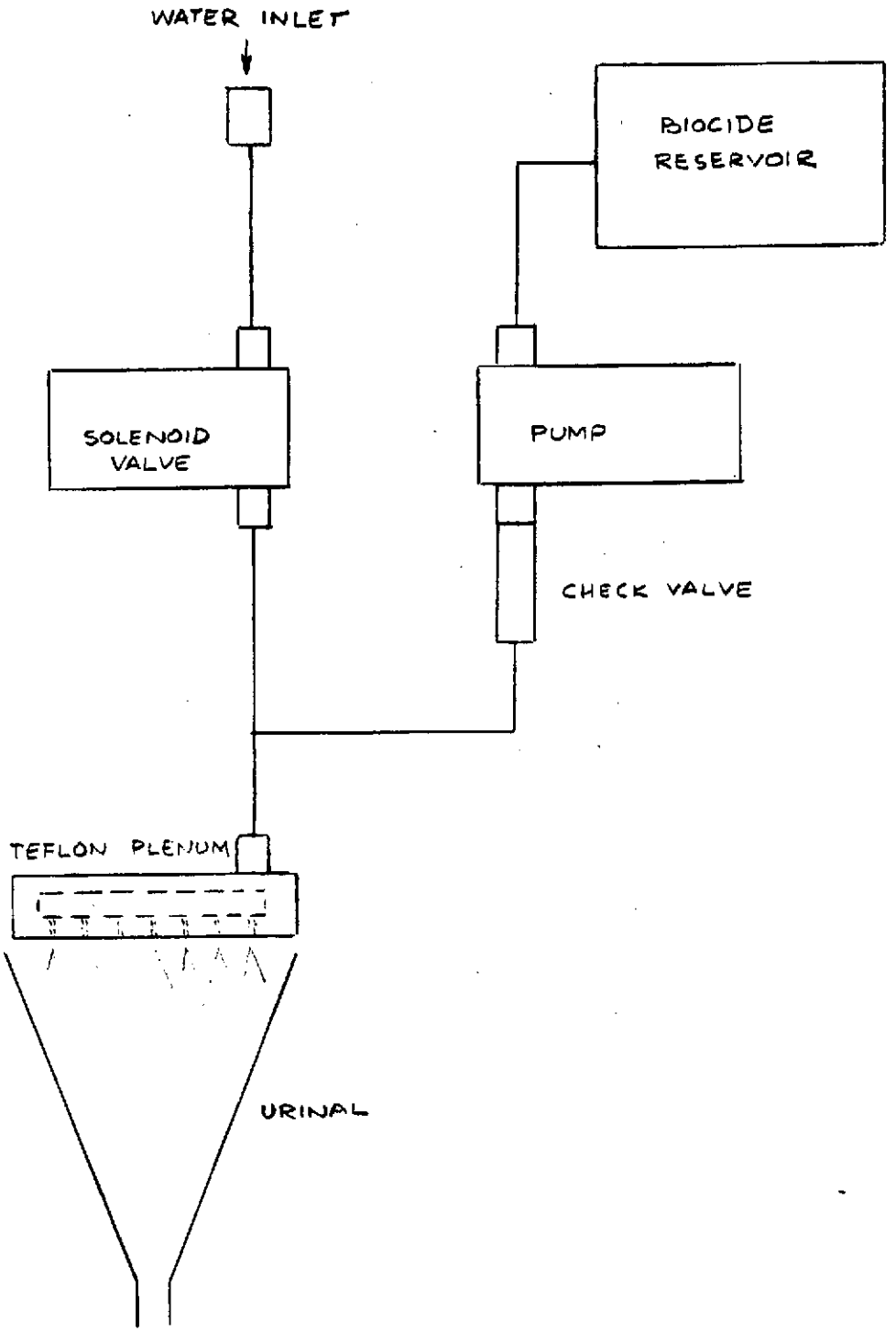


Figure 4.8-1. Biocide and Flush Water Assembly

During the disinfection cycle, 10 ml of Betadine solution are first discharged into the line. This is followed by a 100 ml discharge of water. The discharge columns are controlled by timing the operation of the pump and the plenum valve.

Neither flush nor disinfection cycle can be operated unless the urinal is in place. The control is accomplished by means of the microswitch mounted on the urinal installation clamp.

4.9 Volume Reduction Assembly

The volume reduction assembly is located immediately below the top panel and consists of a spring loaded cavity expandable to the full size of a 400 ml pool sample container. The septum is installed into a guide which duplicates that of the pooling compartment. Facing the septum there is an injection assembly the same as used on the fluid dispenser assembly.

The function of the assembly is to remove all fluid in excess of 110 ml and to record the serial number of the container and the identity of the user.

The general configuration of the assembly can be seen in Figure 4.0-4 and consists of the following parts:

1. The cavity with a spring loaded plate which is used to determine the 110 ml volume position. (This is the normal unloaded configuration.)

2. The door which is used to load and retain the sample container in place.

3. The injector assembly used to remove the excess fluid from the container.

4. The light sensor assembly to "read" the serial number and I.D. of the container from the tag.

5. The pump which is identical to that used for the biocade dispensing. The pump is connected to the "dump" port.

The pumping cycle is controlled by a limit switch on the shaft of the spring loaded plate. Pumping will occur only as long as the plate is not in the normal 110 ml position.

4.10 24 Hour Pool Compartment

The 24-hour pool compartment is used mainly to collect and temporarily store the 10% proportional sample from the micturation of each user. It is also used for the installation of the real time sampler and the return septum. This is due to the mechanical necessity of keeping all septa installed in such a way as to minimize misalignment.

The basic structure of the assembly is shown in Figure 4.10-1 viewed from the top and Figure 4.10-2 viewed from the bottom. Some of the insulation and the front door are omitted.

4.10.1 Pool Compartment

The pool compartment proper is an insulated box approximately 8 x 8 x 7 inches mounted on a pair of telescoping slides. The box consists of two cold plate heat sink assemblies, mounted back to back with the cold plates forming the compartments for the installation of the pool sample containers. There are three compartments on each side facing the insulated access doors. The heat sink plates are joined to form a finned trough. The heat transfer from the cold plate to the heat sink is accomplished by means of eight Thermoelectric units, Cambion part # 3959-01(801), equally spaced and connected into two parallel

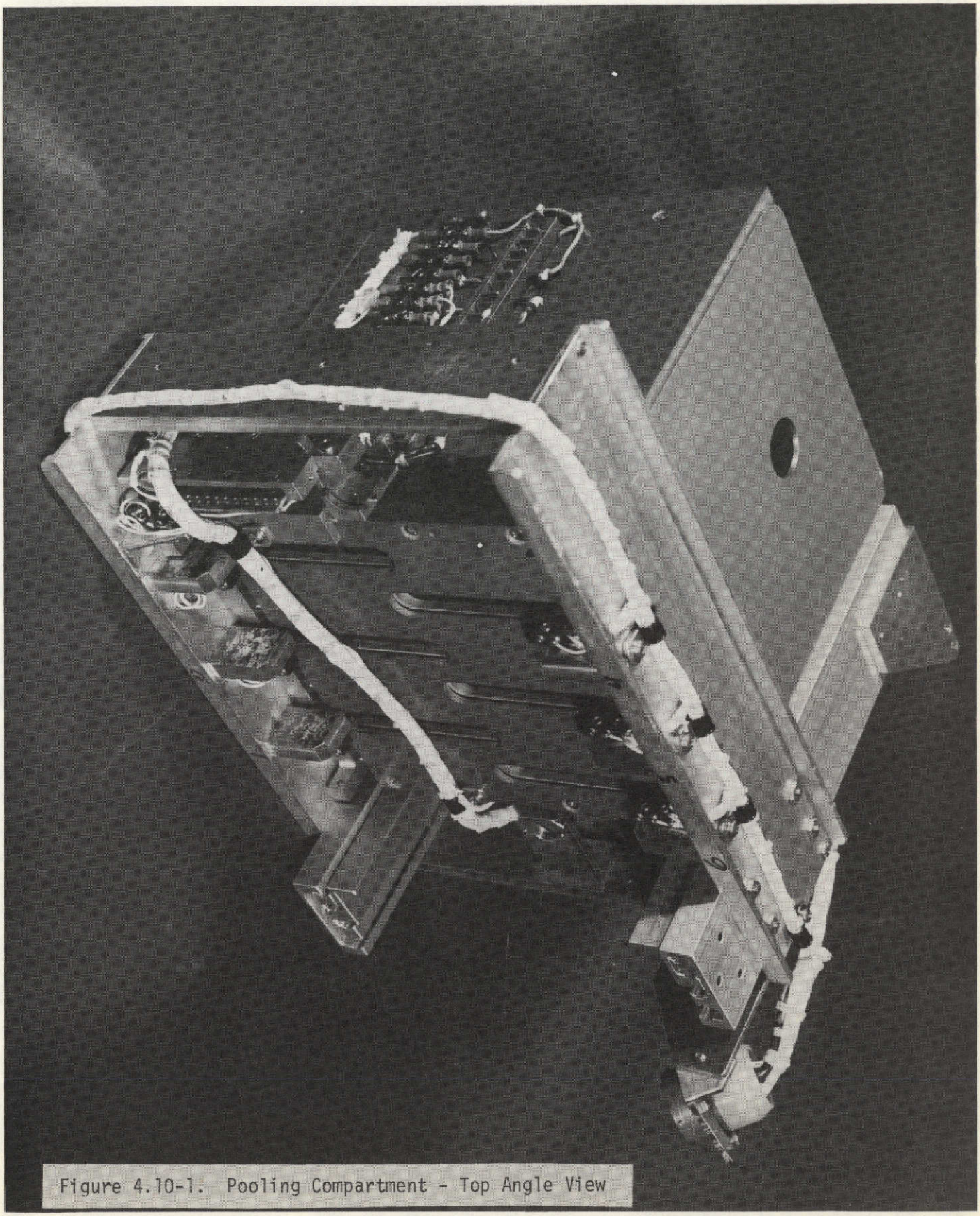


Figure 4.10-1. Pooling Compartment - Top Angle View

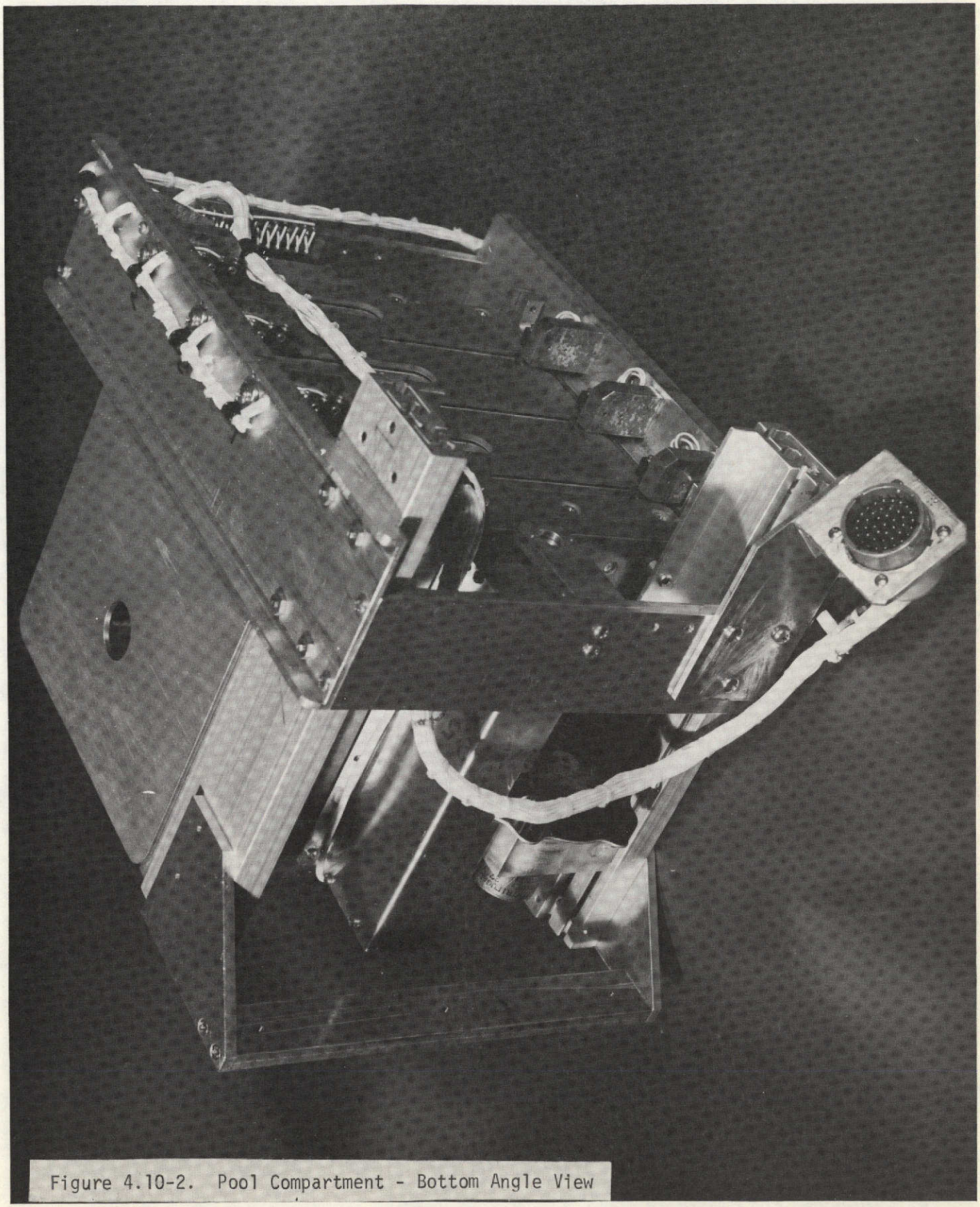


Figure 4.10-2. Pool Compartment - Bottom Angle View

loops drawing a total of 40 watts. The temperature of the compartment is controlled by a sealed thermostat, Texas Instruments part number 4286A2, with closing temperature set at 50°F. The heat sinks are cooled by forced air conversion.

The air flow is provided by a miniature centrifugal blower, Globe part number 19A1860, connected to the heat sink by means of a plenum. The blower and the plenum are visible in Figure 4.10-2.

The pool sample containers are installed by sliding the tab and septum of the container in the groove provided for each compartment. The length of the tab is such that it assures the proper position and each septum once the side doors are closed.

The pooling compartment is mounted on slides so that it can be pulled out of the normal working configuration for the purpose of loading and unloading new sample containers.

The slides, Arant Dynarace part number DR3901A, are held by a rectangular frame made of two side channels and top and bottom plates. Mounted on each channel, there are three blocks in line with each of the tabs in the pooling compartment. Each block holds a limit switch to verify the presence of the container prior to the discharge of fluid. The blocks also hold a combination of one to three pins which penetrate the tag on the installed sample container so that the tags are permanently identified, with user ID, in binary code with the particular pool compartment position.

The compartment doors are lined internally with thick foam rubber. The foam is used to insulate the cold compartment and to keep the sample containers in place.

4.10.2 Real Time Compartment

The real time sample compartment is clearly visible on top of the pooling compartment in Figure 4.10-1. The device is designed to perform the following functions:

It holds the real time sample container in place with the septum in line with the fluid dispenser. The sample container is kept in place by a latch which must be released prior to installation or removal of the containers. The septum is held in place very much like the pooling compartment septa. The significant difference is that the sample is not cooled since it should be removed immediately after collection. Also the tag serial number is "read" in place by a light sensor assembly similar to the one used for the volume reduction compartment.

4.10.3 Return Septum

The return septum is the same as used on the sample containers. It is held in place on the bottom plate bracing the channels and slides of the pooling compartment. The mounting bracket can be seen in Figure 4.10-1 and Figure 4.10-2. It is easily removable and replaceable by removing the two screws that hold it sandwiched between the mounting bracket and the connecting fitting.

4.11 Programmer

4.11.1 Description

The programmer consists of the electronic hardware used to provide interface circuitry for input and output electromechanical devices, and the logic circuitry necessary to generate the timing, control and telemetry formatting required by the subsystems. A block diagram (GE Dwg ER47D220983) shows the key functional elements in the programmer. The circuitry is implemented with integrated circuits comprised of operational amplifiers for the linear circuits and C-MOS digital circuits for logic and signal processing. The C-MOS circuitry provides excellent noise immunity and minimal power consumption consistent with on-board space equipment design goals.

4.11.2 Programmer Inputs

The programmer inputs for the most part are digital signals derived from switches or position sensors, see paragraph 4.14. The operational sequence is determined by the manual control of the user and the Valve Control or Dispenser Control Electronic sections. Limit switches are used to derive end of travel signals to protect the electro-mechanical devices and override switch inputs are provided for manual position control of the mechanical subsystem elements.

4.11.2.1 Programmer Input Buffer Circuits

Input buffer circuits are used to convert the transducer output circuits into digital circuits, which are electrically compatible with the C-MOS microcircuits. The interface buffers consist of LM211 comparator circuits used to convert analog signals to digital signal. The operating point of the comparator is adjustable by means of a potentiometer accessible on the analog circuit board.

4.11.3 Programmer Outputs

The programmer output circuits are power stages capable of suppling drive current to relay circuits or D.C. motors. The logic signal energizes a current driver DH0006 which can deliver a peak current of 1.5 ampere and continuious current of 300 milliamperes. Since some of the motors require heavier current (at stall current conditions) some of the DH0006 power circuits are used to drive 2N2880 power transistor in an emitter follower configuration. This type output stage can deliver a peak current of 5.0 amperes.

The programmer also provides the telemetry data to the printer.

4.11.4 Frequency and Time Code Generator

The POWER ON switch applies voltage to the logic circuitry part of which is a frequency and time code generator. This circuit consists of a series string of C-MOS digital counting circuits driven by a 455 HZ clock used to derive the programmer clock frequencies which are binary division of the 455 HZ clock. The time code generator is a series of decade counter driver by a 0.00278 HZ clock which is derived from the 455 HZ signal. The time code counter stores the time from power turn-on in increments of 0.1 hour and has a capacity of 999.9 hours. This power on time is multiplexed into the telemetry data. This circuitry is shown on GE Dwg. ER470220980 Sheet 1.

4.11.5 Dispenser Electronics

The Dispenser Electronics positions the needle carriage and needle in response to the URINE START and URINE SAMPLE signals. The Dispenser Position, Needle Engaged and User ID signals are used to insure that the needle carriage and sample container are in the proper position and the needle in engaged. In the event the equipment is not in the return postion, the URINE START or URINE

SAMPLE lights will flash alerting the operator that the system is not ready for use or for the sampling and operation is inhibited. The circuitry consists of C-MOS logic gates used to derive the required logic states to enable the Valve Control, Volume Measurement, Flush and Disinfect Electronics. This circuitry is shown on GE Dwg. ER47D220980 sheets 2, 3 and 13.

4.11.6 Valve Control Electronics

The Valve Control Electronics provide the drive signals for the fluid flow valves in response to the fixed programmer sequential logic control circuits. There are two routines during which the valves are sequenced, the sample cycle and the disinfect cycle.

When the SAMPLE signal is activated, the valve control logic recirculates the fluid through Volume Measurement elements and sample gathering elements. This done in a fixed sequence where logic gates are satisfied to activate the appropriate valve to control fluid flow until the sample sequence is complete.

When the DISINFECT signal is activated the valves and fluid are sequenced through the disinfect cycle which disinfects, purges and flushes the system. During this sequence logic gates are used to activate the valves in a fixed sequence to ready the system for its next use.

C-MOS gates and counters are used to implement the desired logic sequences. The circuitry is shown on GE Dwg. ER47D220980 sheets 1, 2, 3, 4, 6 and 8.

4.11.7 Volume Measurement Electronics

During the sampling sequence the fluid is transferred to an accumulator and volume measurement is performed by discharging the fluid from the accumulator.

As the fluid is discharged an incremental volume sensing transducer provide digital inputs to the Volume Measuring Electronics. The digital signal is used to clock a binary counter decoded for 1 ml volume increments. The 1 ml signals clock decade counters (3 significant digital) which provide output BCD data to the multiplexer for transmittal to the printer. A sample as large as 999 ml can be measured during one sample period.

In the event a small sample (< 50 ml) is measured, as determined by the pressure transducer comparator, the SMALL SAMPLE light will flash. A real time sample container must be inserted so that the small sample sequence can be initiated. Sample less than 50 ml are not measured and are discharged into the real time sample container by depressing the SMALL SAMPLE switch.

After completion of the sample sequence, or small sample sequence, the system returns to the return position and all indicator are turned off, except the POWER ON light.

The Volume Measurement circuitry is implemented by C-MOS logic gates, binary and decade counters. The measurement sequence is controlled by the accumulator discharges and the fixed logic sequence of the Valve Control Electronics. This circuitry is shown on GE Dwg. ER47D220980 sheet 5 and 9.

4.11.8 Volume Reduction Electronics

The Volume Reduction Electronics provide the drive signals to discharge the fluid from the systems. These signals engage the Volume Reduction needle and energize the Volume Reduction pump. The VOLUME REDUCTION switch initiates the cycle and all fluid except 110 ml is discharged from the system.

The circuitry is shown on GE Dwg. ER47D220980 sheet 10.

4.11.9 Multiplexer and Printer Control

The Multiplexer and Printer Control selects the desired system data and transmitts this data to the printer. The printer generates a hold command to prevent data scrambling during the print cycle. The data is selected prior to the flush cycle and can be taken in the following modes:

Sample	FIRST LINE	User ID, Mission Time
	SECOND LINE	Volume, Container #
Volume Reduction		FIRST LINE ID (Pool), Mission Time
		SECOND LINE User ID, Container #
Disinfect		ID (Sterilize), Mission Time

A manual print can be taken any time the User selector switch is not in the reset position. The manual print data format is the same as a sample print cycle. The multiplexer is implemented with C-MOS bilateral switches, AND-OR Select Gates, flip-flops and other digital circuits. The multiplexer input data is supplied from the various electronic sections described in paragraphs 4.11.4 through 4.11.8.

The circuitry is shown in GE Dwg. ER47D220980 sheet 7.

4.12 Power Conditioning

4.12.1 Primary Power Requirements

The Urine Subsystem can operate from any power source that supplies + 28 $\pm$ 2 VDC at 10 amperes. When the equipment is operated from a laboratory power supply, the ripple on the input power lines should not exceed 100 MV. The power source should be turn on and adjusted to the proper voltage prior to activating the POWER ON switch.

After the POWER ON switch is activated, a visual indication is illuminated to signify that primary power is applied to the Power conditioning circuitry. Should this indicator not be illuminated the POWER ON switch should be activated again and the primary power input circuit should be checked for proper voltage and/or connection to the equipment.

4.12.2 DC to DC Converters

Two DC to DC converters are used to develop the required operating voltages for the electronic circuits and for the cooling compartment thermoelectric circuits.

A Burr Brown Model 528 is used to develop ± 15 VDC for the operational amplifiers and servo amplifiers. The + 15 VDC supply is used to develop + 12 VDC and + 5 VDC required to drive the logic circuits. This converter is capable of delivery 6.0 watts.

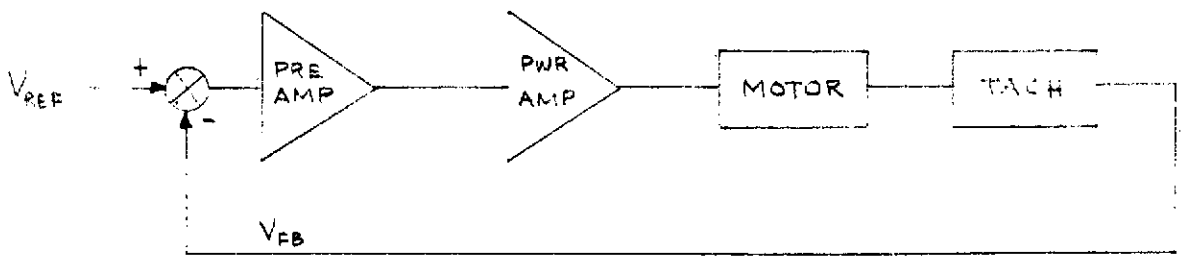
A Technipower Model CD 5.5-8.0 is used to develop the + 5.0 VDC required to power the thermoelectric elements in the cooling compartment. This converter is capable of deliverying 40 watts.

4.12.3 DC to AC Converter

A DC to AC converter is used to develop the power for the air Transport Blower. The converter is a Datac Model BC 333 type 256 and supply 26 VAC at 400 HZ capable of delivering 62 watts.

4.13 Phase Separator Speed Control

The Phase Separator speed is controlled by a closed loop linear servo loop. The loop is shown on the next page.



The phase separator speed can be adjusted by varying the reference voltage V_{REF} by means of a potentiometer. The servo loop consists of a preamplifier a power amplifier, a direct current motor and a tachometer generator.

4.13.1 Preamplifier

The preamplifier consist of a solid state operational ampflifier used to develop the power amplifier drive voltages from the sum of the reference voltage and tachometer feedback voltage inputs. The amplifier is stablized using a single lag feedback network which also attenuates the tachometer signal noise. The power amplifier drive voltage and phase separator speed can be increased by an increase in reference voltage. A decrease in the reference voltage will decrease the phase separator speed.

4.13.2 Power Amplifier

The power amplifier is an Inland Motor EM 1802 servo amplifier with a gain characteristic of 20 volts/volt. The power amplifier is capable of delivering 200 W from the power output bridge circuit. The bandwith of the amplifier is 10K HZ for small signals and 1 K HZ for large signals.

4.13.3 Tachometer Generator

The Tachometer Generator is an Inland Motor Model TG 2916 and a description is included in Appendix 7.4.

4.13.4 D.C. Motor

The D.C. Motor is an Inland Motor Model T2955 and a description is included in Appendix 7.4.

4.14 Position Sensors

Position sensors are used to locate the Needle Carriage at the selected user position and to read (into the telemetry data) the sample container number in the Cooling Compartment or the Volume Reduction Compartment. The position sensors are optoelectronic devices, Texas Instrument TIL 138, which are compatible with Integrated circuits used in the programmer. The optoelectronic device consists of a gallium orsenide light emitting diode and a NPN silicon phototransistor mounted in a plastic housing. Performance Characteristics of the device remain stable when operated in high-humidity conditions.

4.15 Printer

The printer is a Practical Automation Inc. Model CMMP-6A Be six channel machine. The circuitry consists of solid state TTL and discrete part semiconductor power output circuits. The 120 VAC 60 HZ input power is converted to secondary DC and AC voltage needed to drive the internal circuits.

The input data to the printer is binary coded decimal (4 bits per channel) and a print command and the printer output data consists of six channels of decimal numerics (0 to 9). The printer is capable of printing greater than one line/second.

5.0 VERIFICATION TEST RESULTS

Laboratory tests were performed to verify or determine the operating performance of the ABSS urine subsystem.

5.1 Tests Conducted At The Component Level

5.1.1 Transport-Air Blower

Purpose of Test

Verify vendor supplied air flow and pressure drop data.

Test Setup

The blower was connected to a Venturi calibrated for air flow between 0 to 10 CFM.

A water manometer was connected to the line between the blower and the Venturi. The Venturi exhausted to ambient through a manual valve used to create the back-pressure required for flow regulation.

Test Results

Measurements were made at free flow (no back pressure), no flow (maximum back-pressure), and several intermediate points. The results are shown in Figure 5.1.1. The vendor's data is plotted against the test data.

The tests show that the blower exceeds the performance specifications supplied by the vendor.

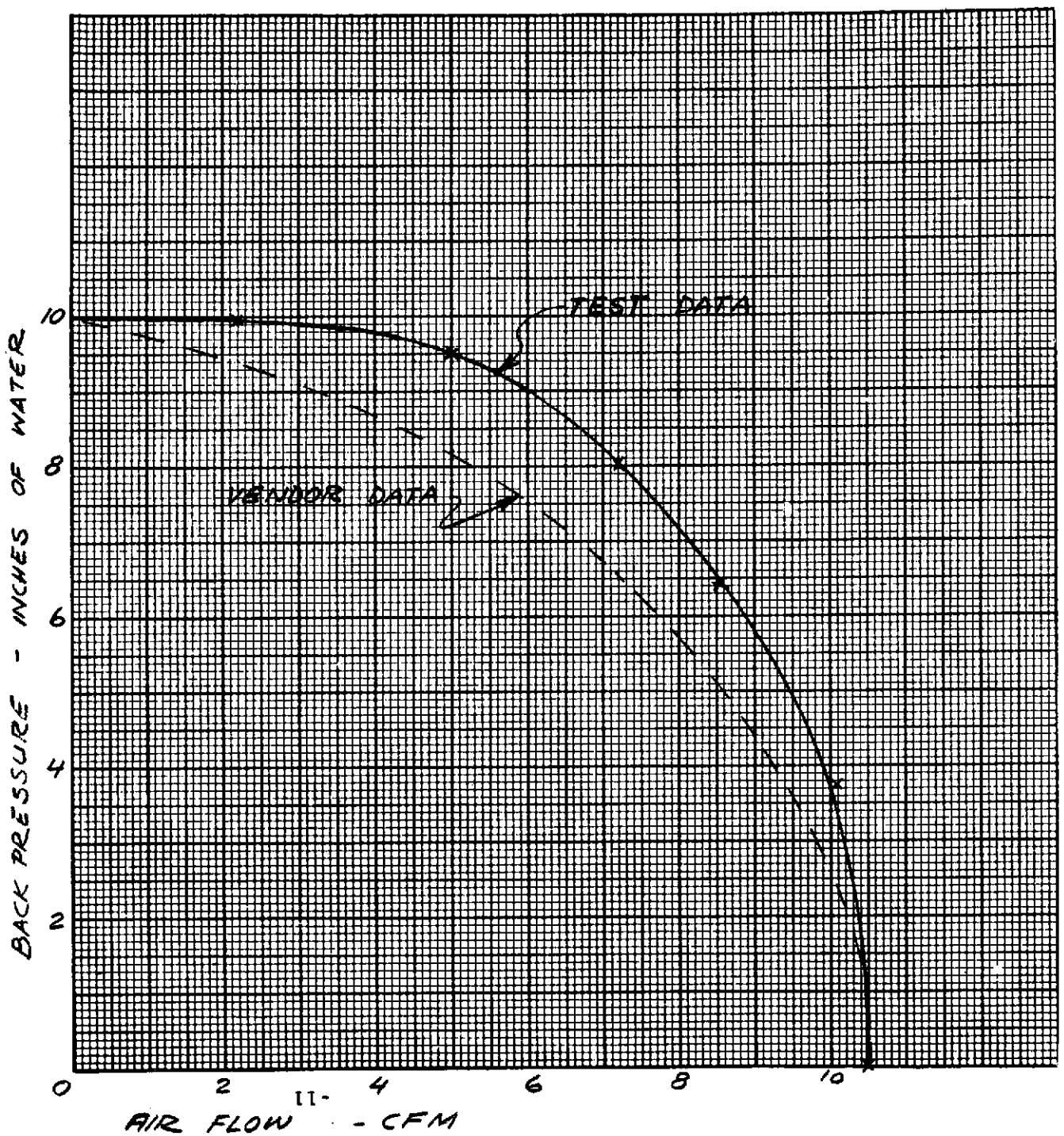


Figure 5.1.1 Air Blower Performance (Rotron Mfg #RRFP-RS-201)

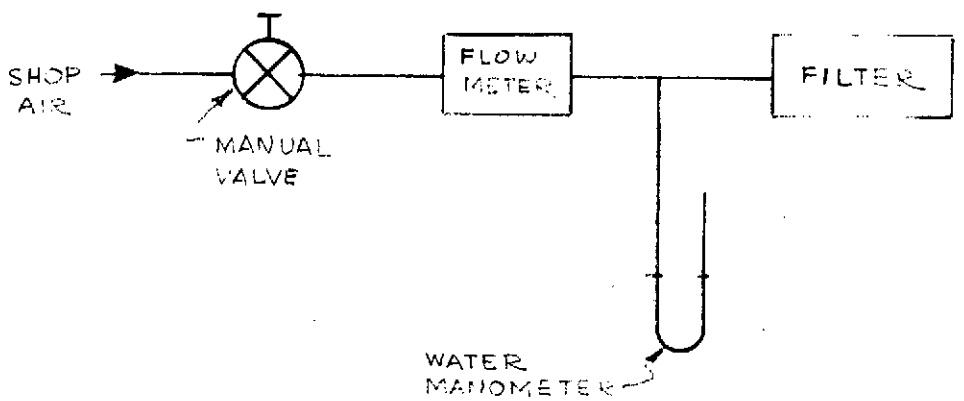
5.1.2 Transport-Air Flow Filter

Purpose of Test

Determine pressure drop for air flows ranging from 0 to 10 CFM.

Test Setup

The transport air flow-filter was tested by connecting the filter directly to an airflow meter calibrated in the range from 0 to 10 CFM. Pressurized shop air was used as the effluent. Regulation of air flow was achieved with a metering valve at the shop air outlet. Pressure measurements were made with a water manometer connected between the flow meter and the filter as shown below:



Test Results

The pressure drop through the filter was measured in 1.0 CFM airflow increments up to 10 CFM. The measurements were repeated on a second unit. The results are shown in Figure 5.1.2. Note that the drooping characteristic is due to flow thru the filter from the inside-out rather than the normally used outside-in direction of flow. This causes an increase in effective area at higher flow rates.

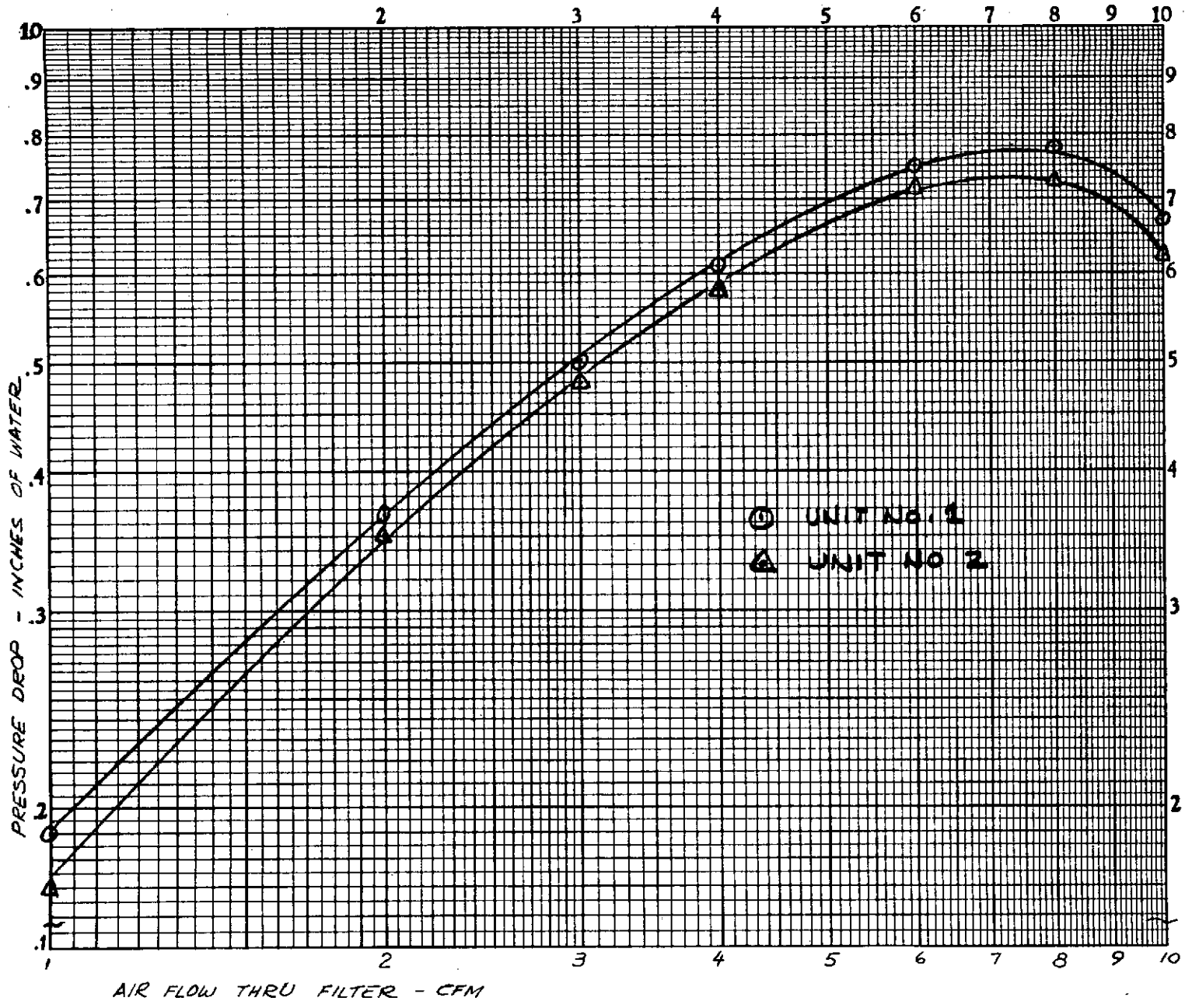


Figure 5.1.2 Filter Performance Test Data (PTM Corp #MCS 4463UP)

5.1.3 Biocide/Volume Reduction Pumps

Purpose of Test

Verify vendor supplied liquid flow and pressure drop data at urine subsystem operating voltage.

Test Setup

The system requirements are only a small fraction of the pressure and flow rate capability advertised by the pump manufacturer. As a consequence only one pump was fully bench tested while the second pump was checked out only to verify that it was in operating conditions.

The pump tested is identified by serial #08-35-101-224.

The inlet of the pump was connected to a water reservoir, the outlet to a collection beaker. After purging the air from the lines the pump was operated at the rated 27 V.D.C. for a period of one minute at a nominal no back pressure. The effluent was then measured by weighing on a Mettler scale.

After the above test, the outlet of the pump was connected to a throttling valve. A pressure gage was placed between the pump and the valve. After again priming the system, the throttling valve was set to produce a backpressure of 5 psig. The effluent over a minute period was connected and measured.

Test Results

1. Flow at nominal no backpressure = $\frac{808 \text{ cc's}}{\text{min}}$ av = 14 gal/hr

2. Flow at 5 psig backpressure = $\frac{387 \text{ cc's}}{\text{min}}$ av = 6 gal/hr

3. Max pressure (blocked flow) = 7 psig

The vendor test data indicates 21 gal/hr for no back pressure, 15 gals/hr for 5 psi back pressure and 11.5 psi for blocked flow. Our test results are significantly lower than the vendor data and may be due to improper setting of the power supply and differant temperature of the water among the most significant factors which may have affected the results. However the measured pressure and flow rate are still far in excess of requirements and therefore acceptable.

5.1.4 Peristaltic Pump

Purpose of Test

Determine total flow rate and separate flow rate for each of the two pumping chambers.

Test Setup

The test setup consisted of the peristaltic pump with the inlet tubes connected to a water reservoir and the two outlet tubes connected to a single beaker for total flow and to separate beakers for proportional flow. The pump was operated at 24 V.D.C. All measurements were made after priming the system with water. A Mettler scale was used to measure the quantity of fluid pumped.

Test Results

A total of three runs were made to measure total flow. Although the flow of this type pump is not significantly affected by backpressures up to 5 to 6 psig,care was taken to keep both inlet and outlets at approximately the same level. The results were:

Run #1 Flow = 22.1 gms for one minute
Run #2 Flow = 22.5 gms for one minute
Run #3 Flow = 22.2 gms for one minute

Three additional test runs were made to measure the proportional pumping from each chamber. The results were:

		Small Chamber	Large Chamber
Run #4	Flow =	38.5 gm/min	189.0 gm/min
Run #5	Flow =	38.5 gm/min	189.5 gm/min
Run #6	Flow =	38.5 gm/min	189.5 gm/min

The total from the last three runs is slightly higher than the total of the first three measurements 227.8 gms/min vs 221.8 gms/min. The discrepancy might have been due to fitting leakage corrected inadvertantly when modifying the test setup between run #3 and run #4.

In order to maximize the efficiency of the system the proportional flow rates of the pump should match the proportional displacement of the accumulator. The tests on the accumulator show that the small chamber displaces 12% of the total flow. The flow from the small chamber of the pump is

$$\frac{38.5}{277.8} \times 100\% = 16.8\%$$

The 4.8% difference between the accumulator and the pump is nearly insignificant. A closer match could be accomplished only with specially fabricated and selected pumping tubes rather than the standard parts used in the ABSS design.

5.1.5 Phase Separator

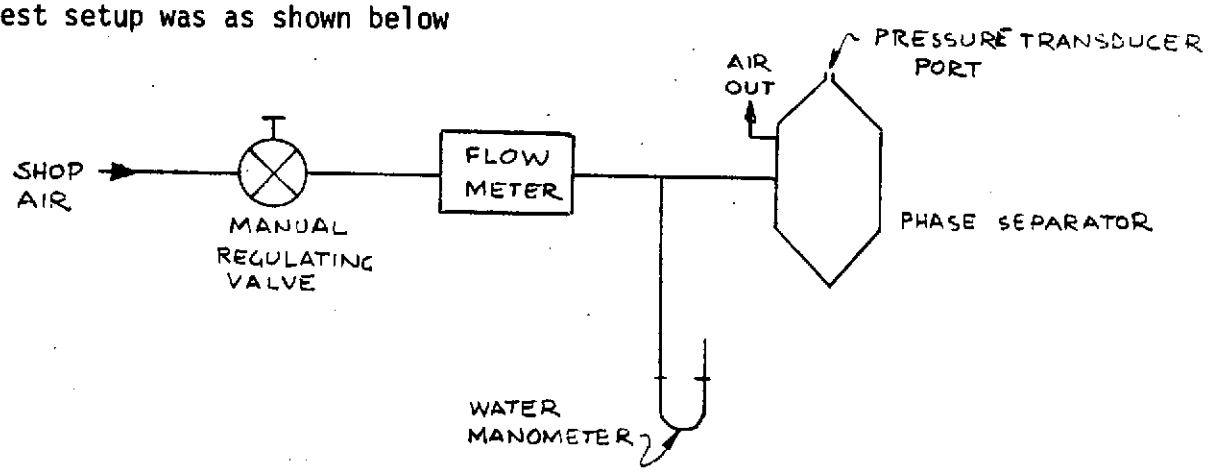
Purpose of Test

Determine pressure drop thru the phase separator for air flows ranging up to 10 CFM (with phase separator rotating at a nominal 400 rpm).

Test Setup

This test was performed with the phase separator wired to the subsystem control electronics in order to maintain the 400 RPM speeds.

The test setup was as shown below



The water manometer was located at the immediate inlet of the phase separator so that the pressure drop measured is only that which is incurred in the phase separator itself at a particular flow rate.

Test Results

Although the air flow rate thru the phase separator is rated at 4 CFM only, measurements were made in the range from 0 to 10 CFM. The same test was repeated with the phase separator impeller assembly inoperative to evaluate the effect of the rotation of the impeller on pressure drop if any. The test showed that there is no noticeable effect. During the first part of the test, the pressure transducer port has been left open allowing the air to exhaust without going through the outlet port. This condition was corrected on run #2 and 3. The data is shown in Figure 5.1.5. Data from run #1 has been included since it gives an indication of the pressure drop though half of the flow path thru the separator.

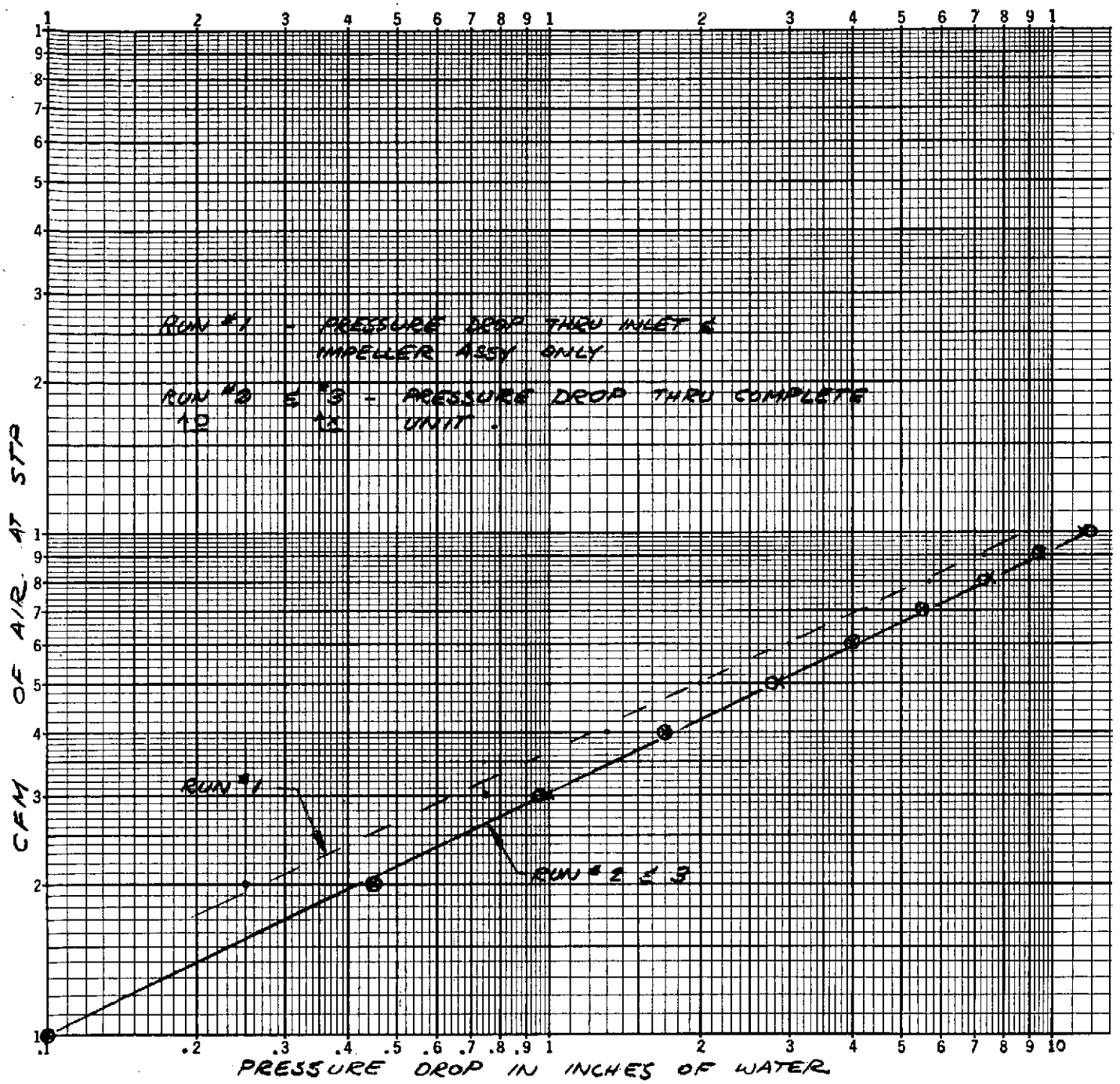


Figure 5.1.5 Pressure Drop Thru Phase Separator Only - Test Results

5.1.6 Dispenser Mechanism

Purpose of Test

Determine positional accuracy and repeatability of dispenser assembly.

Test Setup

The tests were made using a working prototype of the fluid dispensing mechanism. The prototype was functionally identical to the final hardware except for the use of microswitches instead of optoelectric sensors. A sample sensor was tested separately for convenience by moving a mask across the emitter/receiver gap and recording the output signal at various positions.

Test Results

The tests on the ability to position and control the fluid dispensing mechanism were performed during the early phase of the program.

The tests were mostly qualitative and were aimed at evaluating possible problems and solutions. The activities were reduced to three areas of interest.

a) Stopping the drive mechanism where required. Tests showed that the motor could be stopped without significant overshooting of the target. The tendency of the motor continuing to turn due to inertia was sufficiently reduced by the gearing down to the relative low RPM required.

   The overshooting of the target could be significant only in the direction of travel for the carriage. Overshooting in the direction of injection or disengagement of the needle is not critical. In all cases the drive motor could be stopped so that the injection needle was in line with the septum. Also the needle could be driven into and out of the septum satisfactorily.

b) Alignment of the light sensors with the required stop for the eight positions (i.e., return septum, real time sample, six pooling positions) of the pooling compartment.

This was resolved by setting up the pooling compartment above a datum plane. The relative position of the exact centerline of each septum was measured with a vernier gage. The light sensors were then mounted on a plate with the exact same spacing so that once one sensor is in line all the others must follow.

The relative position measured were:

Return Septum	=	1.705 inch Above Datum Plane
Pool #1	=	3.090 "
Pool #2	=	4.095 "
Pool #3	=	5.217 "
Pool #4	=	6.220 "
Pool #5	=	7.345 "
Pool #6	=	8.350 "
Real Time	=	9.938 "

c) Sensitivity of the electroptical device (light sensor) to the position of an object moving across the beam.

This test was performed by moving a mask across the emitter and receiver gap in the sensor assembly. Texas Instrument #TIL 138. The mask was attached to a bernier gauge so that the displacement across the sensing beam could be measured with precision. The sensor was connected to an electronic circuit amplifying the maximum unobstructed output signal to 10 volts.

The test results are shown in Figure 5.1.6 It can be seen that a significant voltage output is obtained with a displacement of a few thousands of an inch travel. This sensitivity is more than adequate for the required application.

5.1.7 Calibration Of Accumulator

Purpose of Test

Establish total discharge volume, proportional volumes, discharge time, discharge pressure.

Test Setup

The test setup consisted of the accumulator with the inlets connected to the peristaltic pump and the outlets connected to the solenoid valves. The valves and the pump were controlled by operation of the "empty" and "full" contact of the accumulator. The inlet of the pump was connected to a water reservoir. The outlet of the valves were connected to collection beakers.

Test Results

Several test runs were made to adjust the travle of the accumulator so that the discharge volume was exactly 25 ml.

Volumes were determined by weight on a Mettler scale.

The discharge volume from the large chamber was found to be 22 ml.

The discharge volume from the small chamber was 3 ml.

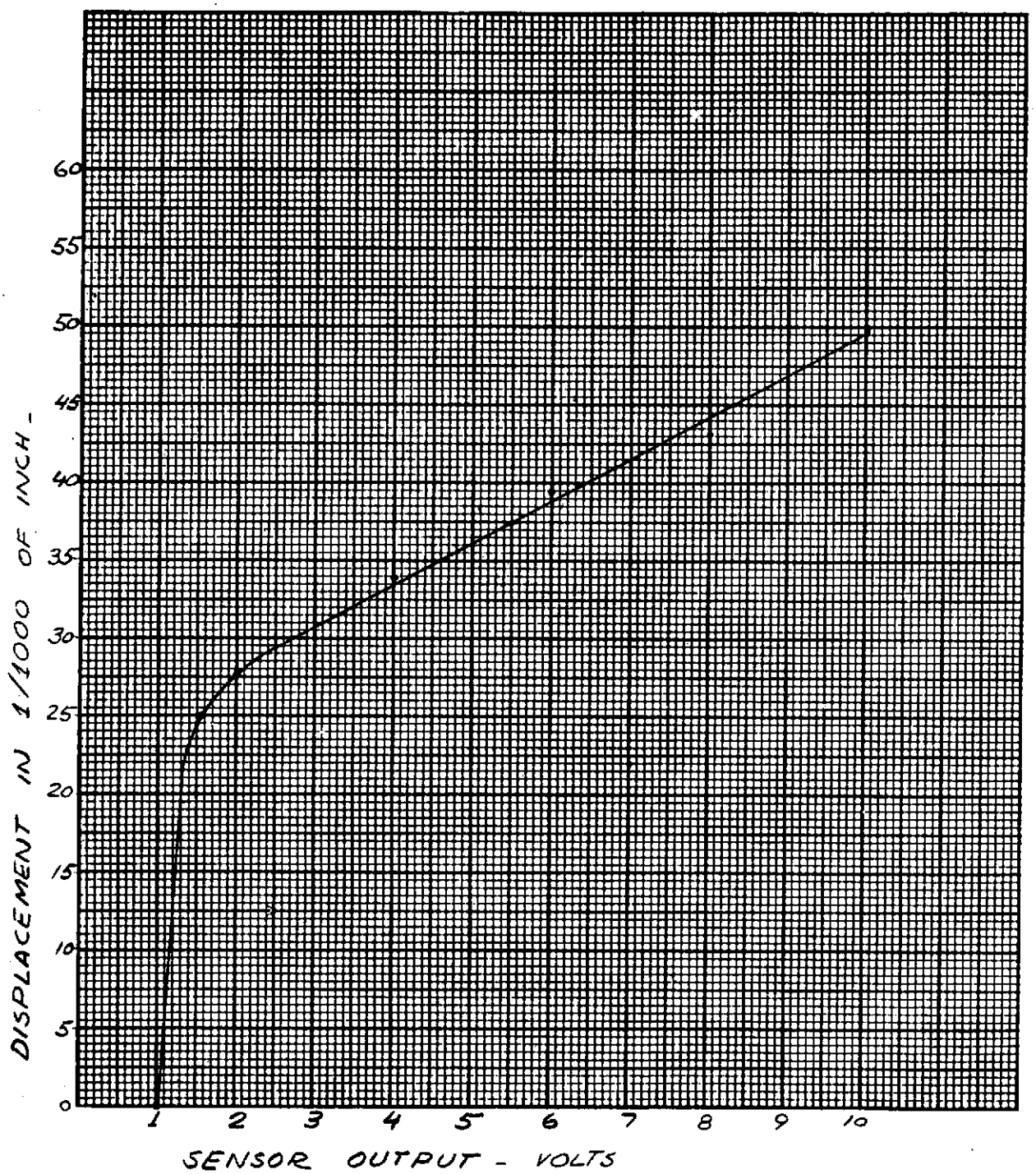


Figure 5.1.6 Response of Positioning Sensor
(Texas Instr. # TIL 138)

The proportional sampling from the small chamber is then

$$\frac{3}{22+3} \times 100\% = 12\%$$

The normal sample required is 10%. This means that a slightly larger amount than required will be temporarily stored during the 24 hours period. The ultimate size of the sample to be preserved by freezing is not affected.

The discharge time was measured at 4.7 seconds, the fill time was measured at 6 seconds.

The discharge pressure was measured at 8 inches of mercury at the beginning of the discharge stroke and 4 inches of mercury ($\sim$ 2 PSIG) at the end of the discharge stroke.

5.1.8 Pool Compartment

Purpose of Test

Determine internal operating temperature achieved under ambient operating conditions and no liquid sample load. After stable temperature conditions achieved, determine temperature/time data within an incoming 50 ml sample from a simulated 500 ml micturition or equivalent.

Test Setup

The test setup consisted of the pool compartment mounted on the slide assembly and with the compartment insulation in place. Four thermocouples were used to record the temperature of the metal surface inside each of the three vehicles on one side and the center while on the opposite side. Two thermocouples where used to read temperatures on the heat sink side, one was used to read ambient temperature. The

thermocouples were connected to a 24 point recorder. The thermoelectric elements were connected to the actual power supply used in the ABSS system. The cooling blower was connected to an external 28 V.D.C. power supply. The thermoswitch designed to control the temperature within the required level (5° to 10°C) was not connected in order to obtain the lowest possible temperature.

Test Results

Several test runs were made trying to optimize the cooling performance of the assembly. The eight elements used in the assembly were connected in one series circuit and also subsequently in two series circuit of four elements each. The various arrangements did not show significant difference as it became obvious that, given a total number of thermoelectric modules, the cooling capability of the system depended mostly on the performance of the heat sink.

Figure 5.1.8 shows the results of one test run where the eight elements were connected in series drawing a total of 7.5 volts at 4 amperes. The temperature of the cooling compartment dropped to the required level in less than 20 minutes. The system slowly stabilized to an average temperature of 48° in approximately 2 hours from the start of the test.

After four hours from the starting time a sample container with 100 ml of water at 70°F was introduced in the pooling compartment. The average temperature of the system went up several degrees as shown in Figure 5.1.8 however in one hour and twenty minutes the average temperature was down to the 40°F level. The test was stopped and the sample was removed from the pooling compartment. The temperature of the water was 46°F.

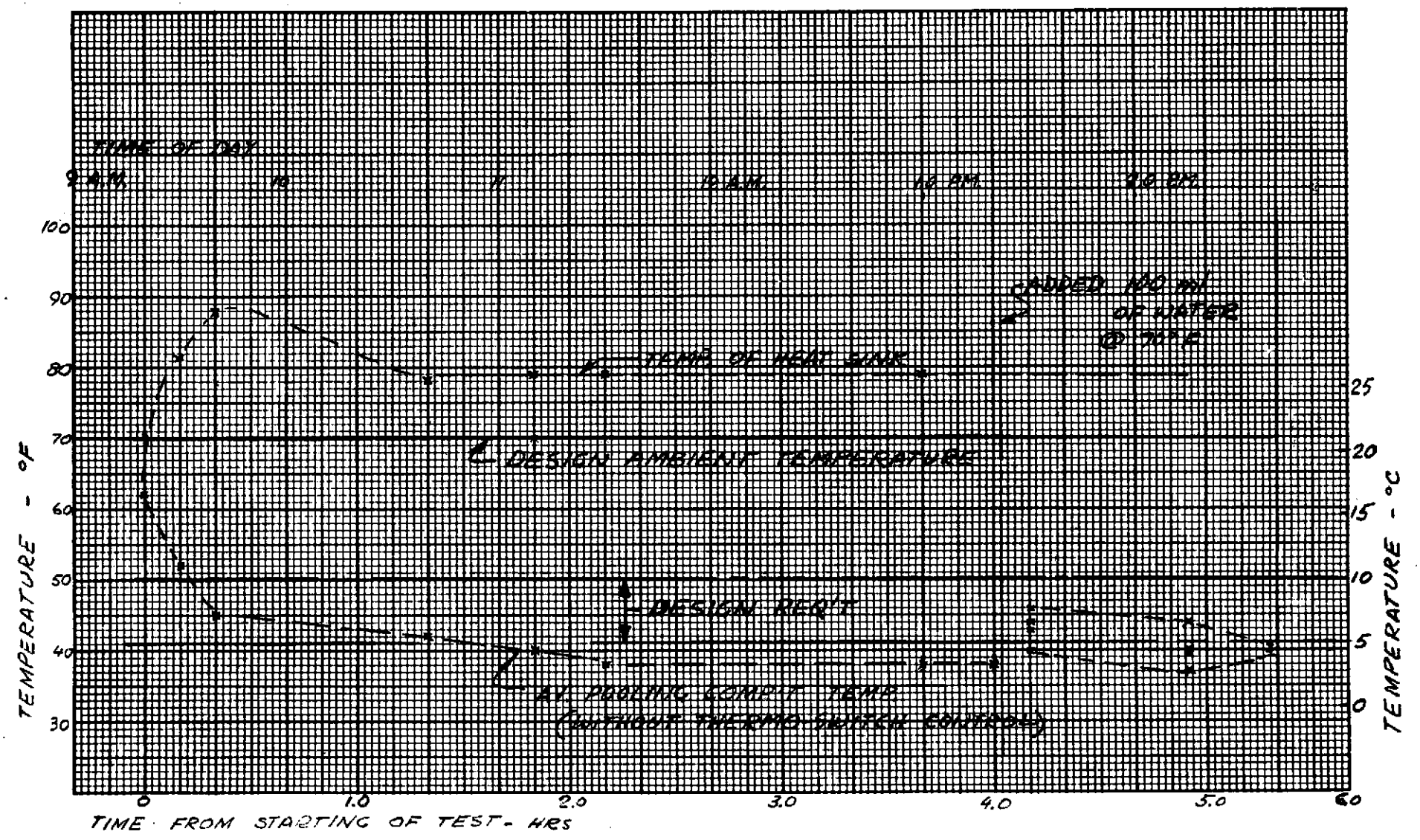


Figure 5.1.8 Pool Compartment Test Results

NOTE: The results of this test have been corrected by a factor of 8°F. The correction factor is due to the difference between the design ambient temperature of 70°F and the actual ambient temperature measured during the test which was recorded at 78°F.

The test indicates that without thermostatic control the system will operate and keep the temperature of the samples in the range of 5 to 10°C as specified provided that the ambient temperature is at 70°F. It is obvious that as the ambient temperature goes up the capacity of the system will become inadequate, requiring additional cooling elements. In view of the relatively cool temperature of the heat sink, less then 10°F above ambient, the addition could be made without significantly upsetting the present design. The present power consumption is 7.5 volts x 4 amps = 30 watts. The capacity of the special power supply provided in the ABSS is 40 watts thus allowing the possibility of an additional 10 watts of cooling. The special power supply is required because the thermoelectric devices used, Cambion part #801-3959-01 operate most effectively at approximately 1 volt and 3 to 4 amps, thus requiring a low voltage, high amperage source of power.

5.1.9 Materials Compatibility

Purpose of Test

Verify compatibility of biocide solution with selected critical materials.

Test Setup

Two Skinner valves of the type used in the ABSS assembly were disassembled. The part of one valve were deposited in a beaker containing a 0.25% Betadine solution.

The parts of the other were placed into a beaker containing a 10% Betadine solution. Only the parts that are wetted by the fluid were used. The parts were removed from the beaker after a period of 30 days.

Test Results

The manufacturers of Betadine had indicated the possibility of light corrosion with parts made of steel other the high grade stainless such as type 304 or 316. Since the valves used in the system contain type 303 and 430F the tests were conducted to evaluate their resistance to corrosion over a period of 30 days. The two solutions duplicate the maximum strength (in the reservoir) and the diluted condition after the Betadine is mixed with water. At the end of the test the parts were removed from the solution, dried, and bagged. The parts were clean and shiney and unaffected by the test. Evidence of slight corrosion appeared on a portion of the base of the valve which had surfaced above water (due to evaporation) in the .25% solution. Even in this case the amount of corrosion was insignificant.

5.2 Tests Conducted At The Subsystem Level

5.2.1 Operational

The operational tests were conducted to verify that the subsystem was in operating condition after the assembly and installation of mechanical and electrical components had been completed. The operational tests took place over a period of several weeks as the system was being calibrated and "debugged". A total operating time in excess of 100 hours has been accumulated without any significant component failure.

The system operating times are shown in the table below:

Table 5.2.1 - S/S Operating Time

Command	Function	Time
Press "START" Button	Use	As Required
Press "SAMPLE" Button	Recirculate	30 secs
(Automatic)	Chemical Sample	23 secs
"	Pooling and Dumping	115 cc's/min
"	Air Purge	51 secs
	Water Flush and Purge	160 secs

From the above table time estimates can be obtained for other system functions. For instance a sterilization cycle using 100 ml of disinfectant with a 30 minutes soaking period would be

Function	Time
Add Disinfectant - (flow rate depending on water pressure)	5 sec
Recirculation	30 secs
Soak Period	1800 sec
Pump Out (dump) - 100 cc/115 ccs/min	52 secs
Purge	51 secs
Water Flush	160 sec
Total Time	2,098 sec

The soak period is presently set at few seconds for the purpose of reducing the waiting period to a minimum while demonstrating the system operation.

The testing of the volume reduction compartment has been significantly affected by the substitution of the planned teflon containers with latex sheet material. The high coefficient of friction between the wall of the compartment and the latex of the container prevents the operation of the volume reduction plates.

5.2.2 Transport Air Flow

Test to verify the air flow through the system conducted by connecting the urinal hose to a venturi calibrated from 0 to 10 CFM. The urinal itself had to be omitted due to the difficulty of obtaining a good seal for the test. The pressure drop through the urinal is negligible, certainly not greater than that introduced in the system by adding the Venturi to the urinal hose.

The first run was made with the phase separator dry. The resulting flow was 4.7 CFM. The second run was made with 500 mls of water in the phase separator. The air flow was measured to be 4.7 CFM. The same results were obtained on the third run with 1000 mls of liquid in the separator.

All measurements exceed the 4.0 CFM minimum required by the subsystem specifications.

5.2.3 Chemical and Proportional Sampling

Test results on the performance of the chemical and proportional sampling are placed together because data were collected for both types of sampling on each test performed even though the chemical sample mode could have been totally omitted.

The size of chemical sample is arbitrarily controlled by the setting of the electrical controls. A range of volumes up to 10 mls is available. Once set, the size of the chemical sample volume remains the same regardless of the volume of urine input.

The size of the proportional sample is controlled by the fixed relative volume of the two chamber of the accumulator assembly. The preliminary tests at the component level described in paragraph 5.1.7 show that the accumulator output are 12% for the small chamber and 88% for the large chamber. The tests at the sub-system level were conducted after the completion of all the mechanical and electrical installations. A summary of the results is shown in Table 5.2.3. The values shown are average values for the number of test listed. The results show that the proportional sampling is slightly closer to the nominal 10% required by the subsystem specification. The values range from 10.2% at the 100 ml level to 11.4% at the 1,000 ml level. Also the size of the chemical sample initially set at 5 ml varies nearly by 0.5 ml above or below an average close to 4 mls. The above variations, although relatively insignificant with regard to system performance became somewhat puzzling when considered in the light of the consistent high accuracy of the volume measurements shown in paragraph 5.2.6. The only logical explanation is that the sampling cycle is started prematurely prior to complete purge of the air from the lines. As a consequence some air is delivered with the liquid into the sample and the pool containers during the first stroke of the accumulator. This explains why the chemical sample size is relatively low and inconsistent. It also explains the relative change in the percentage of proportional sampling. If the amount of proportional samples in Table 5.2.3 is increased by approximately one ml. than all

Table 5.2.3 Summary of Sampling Test Results

Input	Min. No. Tests	Chemical Sample ml	Proportional Sample ml	Dump ml	% Proportional Sample
100	3	3.5	10.2	84.8	10.2
200	10	3.7	21.7	172.5	10.8
300	10	4.1	32.8	261.4	10.9
400	10	4.3	44.2	350	11.5
500	10	4.1	55.8	437.32	11.1
600	10	3.9	67.7	525.8	11.3
700	12	3.7	79	615.7	11.3
800	11	4.0	90.6	702.4	11.3
900	3	3.8	102.5	790.7	11.4
1000	3	3.6	114.2	880	11.4

the percent values shown in the last column of the table will be in the range of 11.3% and 11.4% which are consistent with the high accuracy of the system.

5.2.4 Microbiological Sample

The microbiological sampler was tested by installing the collection portion into the urinal and simulating a direct use with a stream of water flowing at a rate between 0 and 40 mls/sec.

After each use the collector was removed using the same procedure as in an actual use. The wick assembly was then removed from the collector and weighted on a Mettler scale to determine the net weight of urine collected. The test was repeated at least three times. The net weights of the sample collected were no less than 2.5 gm and as much as 3.1 gms indicating than the minimum size of 2 mls of sample can be obtained without difficulty in a real direct use provided that the stream of liquid is made to impinge on the collector.

5.2.5 Small Sample

The small sample cycle was tested several times by introducing less than 50 mls of liquid into the system. When the "URINE SAMPLE" button was pressed the "SMALL SAMPLE" blinking light was automatically energized. After placing the large sample bag at the chemical sample collection port, the "SMALL SAMPLE" button was energized and the subsystem began to operate as required by discharging two strokes of the accumulator into the sample container. This was followed by the regular air purge and flush. When quantities above 50 mls were added the subsystem operated through the normal sampling mode as expected. The cutoff point is not exact; in some tests it exceeded 50 ml by 2 or 3 mls.

5.2.6 Volume Measurement

Figures 5.2.6-1 and 5.2.6-2 illustrate urine volume measurement repeatability and linearity demonstrated by the urine subsystem. For convenience, water was used as the input fluid; sample input mass was accurately determined by use of a Mettler scale. As shown in figure 5.2.6-1, linearity is very good, with the meter reading slightly high but within the $\pm 1\%$ noted in the subsystem specification. An electronics scale factor adjustment can be made to make the meter reading and input more nearly equivalent if desired. Figure 5.2.6-2 shows the one sigma error which can be expected for various sample sizes. Each data point shown represents a minimum of 10 individual test runs (in order to make reasonable accurate error estimates). The increase at large sample sizes was unexpected. One possible cause may be the temperature sensitivity of the pressure sensor which, depending on the sample temperature, would vary the 50 ml cut-off point. A Setra Systems Model 240TC is recommended as a replacement for the currently used Model 237.

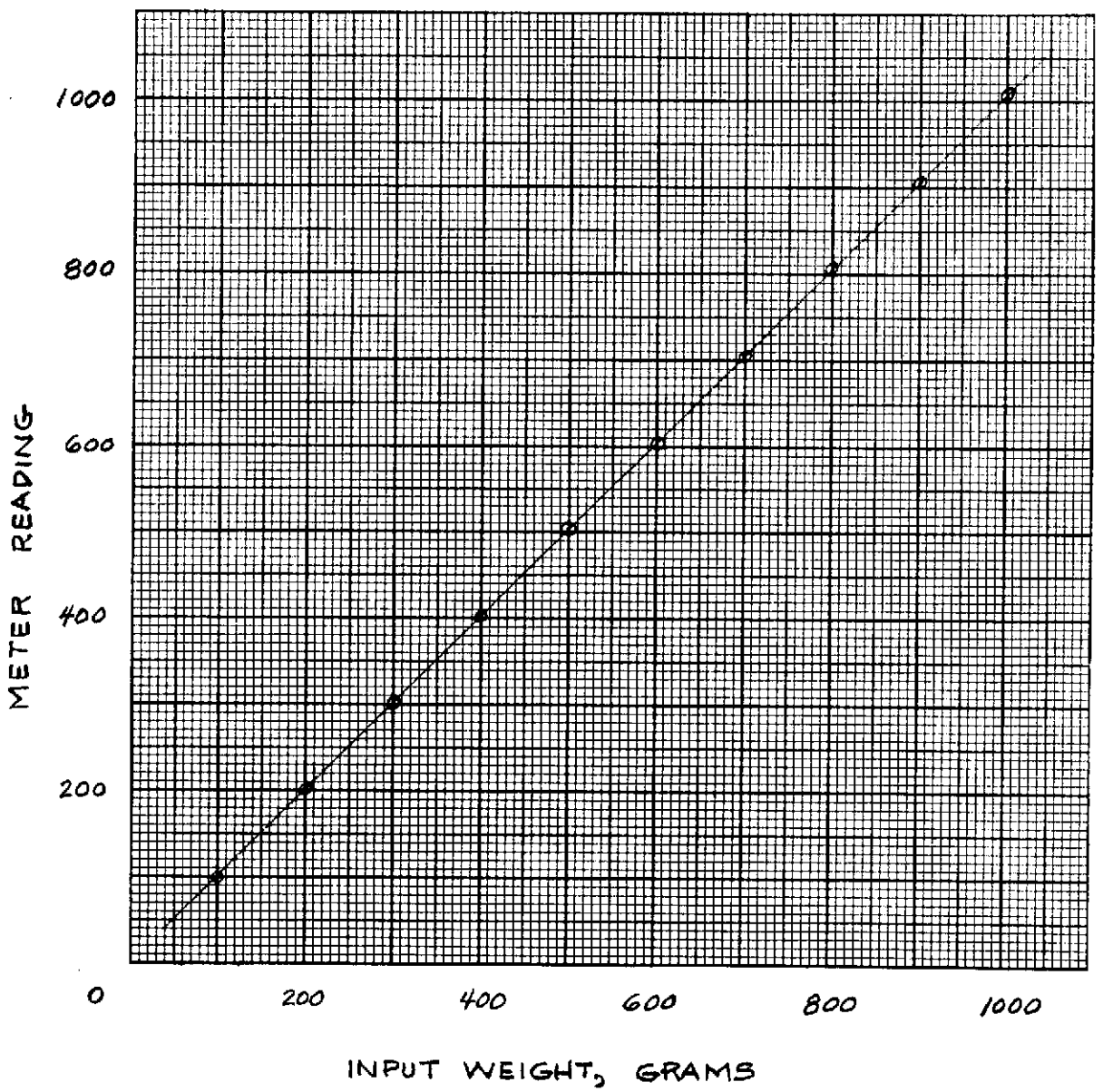


Figure 5.2.6-1 Linearity

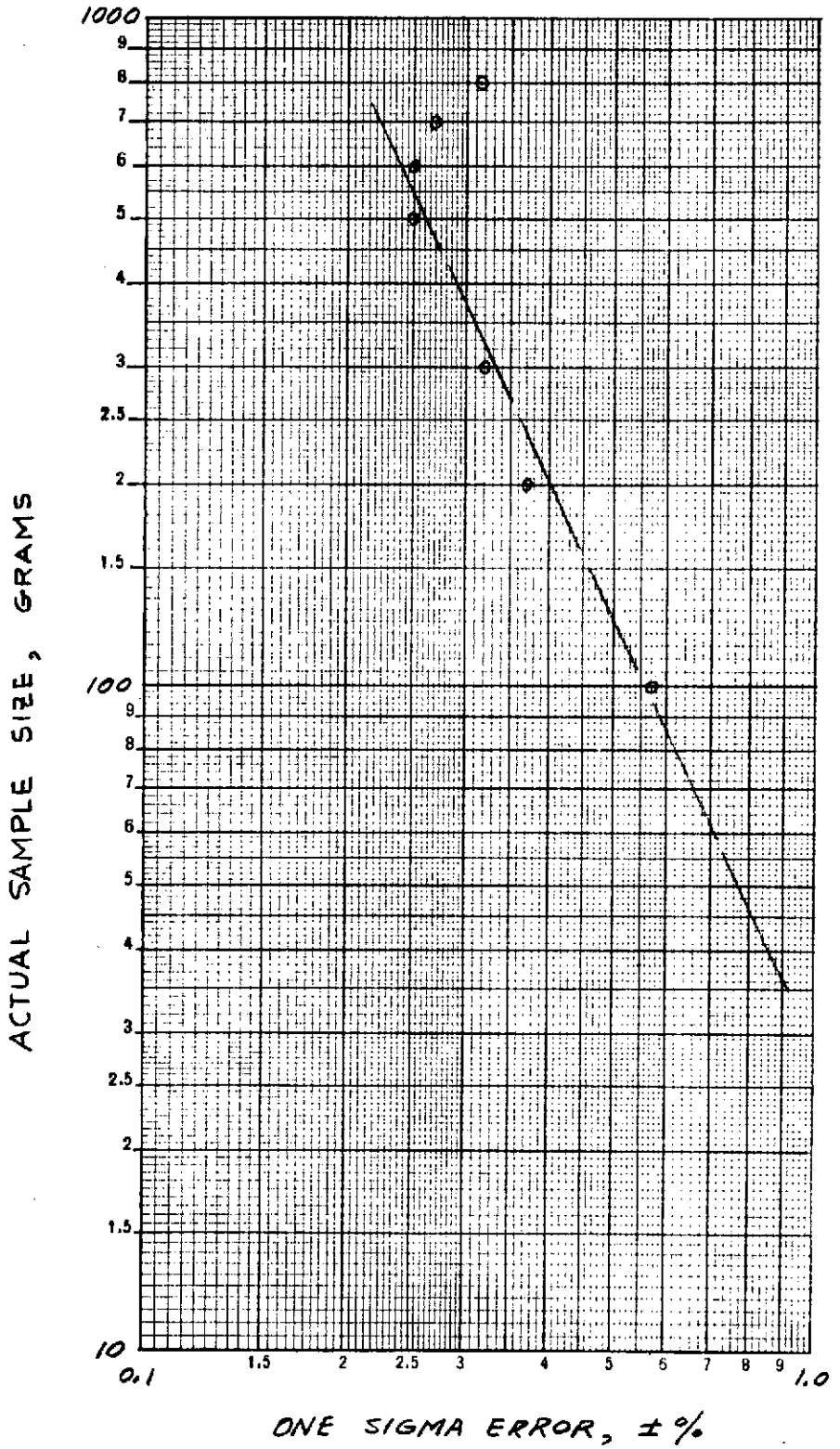


Figure 5.2.6-2 Repeatability

6.0 RECOMMENDATIONS

Recommendations for possible follow-on activity are in three areas; testing, design simplification and incorporation of a real time chemical analyses capability.

6.1 Testing

The Urine Subsystem Operating Model represents a significant advance in automated equipment for urine collection, measurement and sampling. Subsystem level testing was confined mainly to check-out and performance verification activity. Since the Operating Model is a possible precursor to a flight design for SHUTTLE, further testing under simulated flight conditions is recommended. Briefly, a test program oriented towards using live subjects over an extended time period is recommended.

Results of this test activity will be extremely useful in verifying design and operational performance in the following areas:

(1) Multi-man use.

(2) Extended mission time period.

(3) Cross-contamination variation with mission time.

(4) Collection, sampling, measuring performance variation with mission time.

6.2 Design Simplification

The measuring accuracy exhibited by the Urine Subsystem is significantly better than the $\pm$ 2% required. To a large degree, the high measurement accuracy obtained may be attributed to the dual chamber precision accumulator. As noted in Section 4.4, the accumulator assembly consists of the dual chamber accumulator per se, a peristaltic pump to fill the accumulator, control

valving and a linear transducer to readout urine volume increments. This relatively complicated equipment combination can be eliminated by using the phase separator as a calibrated centrifuge. Figure 6-1 shows the estimated accuracy of this approach. Although not as precise as the precision accumulator, the $\pm$ 2% requirement can easily be met.

In addition to mechanical simplification, some simplification of the electronics will also be achieved. Modification of the Urine Subsystem to implement the calibrated centrifuge measurement approach is recommended.

6.3 Real Time Chemical Analyses

The addition of a real time chemical analyses capability is recommended. This capability, in combination with micturition volume, would be useful in assessing the medical health of the crew on a routine, continuous basis during the mission.

The measurement of pH and Sodium, Chloride, Potassium and Calcium ion concentration is recommended. This can be accomplished by integrating Orion flow thru type sensors into the Urine Subsystem so that pH and ion concentrations can be measured and recorded for each individual micturition.

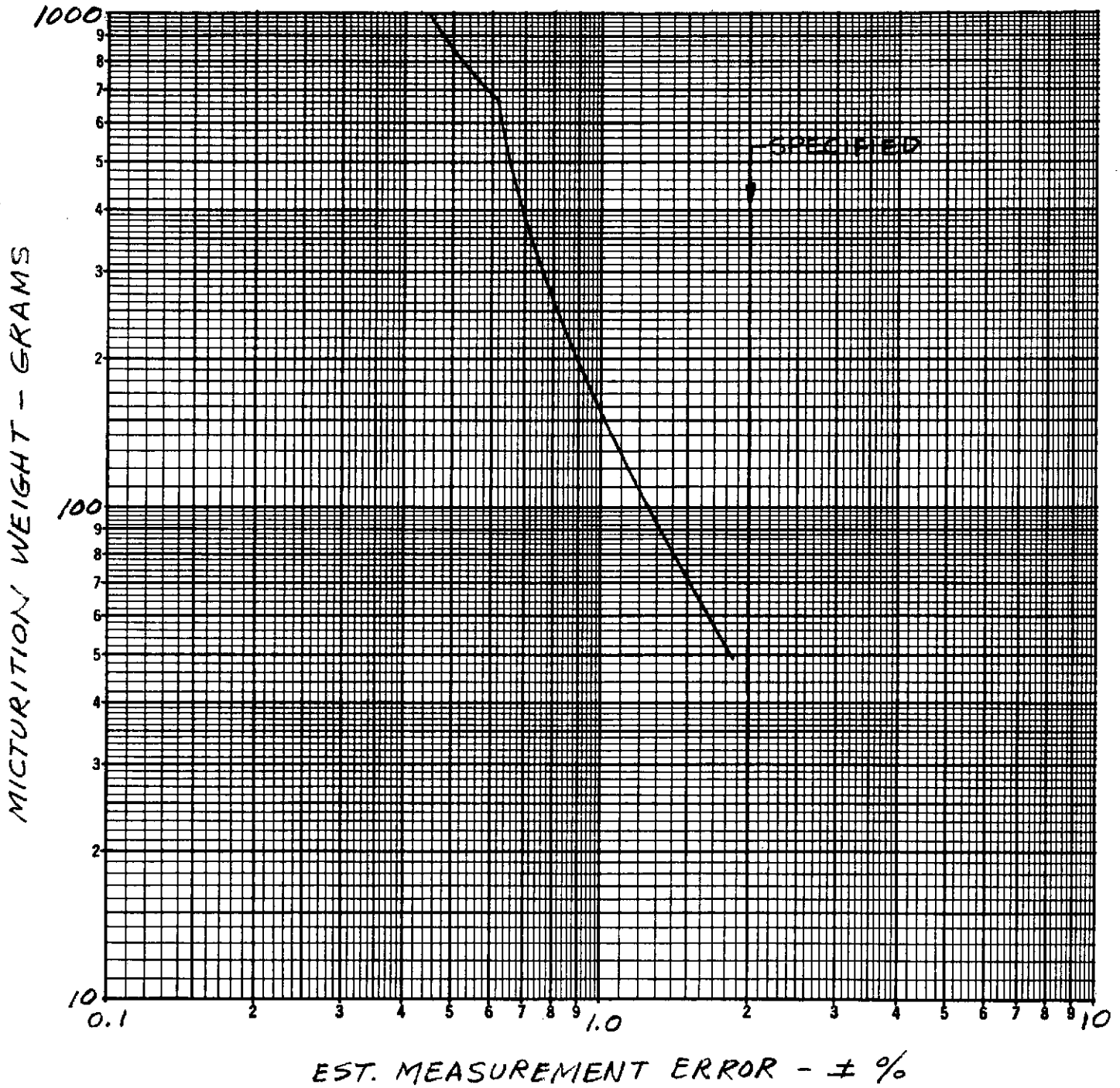


Figure 6-1. Calibrated Centrifuge, Estimated Measurement Error

31 JANUARY 1973

7.1 Design Specification

AUTOMATED BIOWASTE SAMPLING SYSTEM

FOR

MEDICAL RESEARCH

URINE SUBSYSTEM OPERATING MODEL

REQUIREMENTS

SPECIFICATION

Contract NAS 1-11443

Prepared For

National Aeronautics and Space Administration
Manned Spacecraft Center
Houston, Texas

General Electric Company
Space Division
Valley Forge Space Center
P. O. Box 8555
Philadelphia, Pennsylvania 19101

7.2 List Of Drawings

7.2.1 Mechanical

SK56198-700	Urine Subsystem Assy
47D225227	Phase Separator
47C225447A	Housing Inlet Side
SK56198-710	Pooling Compartment Assy
SK56198-711	Cold Plate Compartment Assy
SK56198-712	Heat Sink Compartment Assy
SK56198-713	Cooling Module Compartment Assy
SK56198-714	Spacer Compartment Assy
SK56198-715	Cooling Module Assy Compartment Assy
SK56198-716	Top Plate Compartment Assy
SK56198-717	Side Plate Compartment Assy
SK56198-718	Bottom Plate Compartment Assy
SK56198-719	Door Compartment Assy
SK56198-720	Sampler Comp't Inst.
SK56198-721	Sensor Assy
SK56198-722	Support Sensor Assy
SK56198-723	Holder - Chemical Sample
SK56198-724	Details Real True Sampler
SK56198-725	Receptacle Chemical Sampler
SK56198-728	Support Structure, P.C.
SK56198-729	Detail, Pool Compt.
SK56198-730	Sample Container - 400 mls

DRAWING LIST (Cont'd)

SK56197-731	Sample Container - 10 mls
SK56198-732	Return Septum
SK56198-737	Container - Microbiological Sample
SK56198-738	Shield - Urine Sampler
SK56198-739	Plug Urine Sampler
SK56198-740	Urinal
SK56198-744	Flush
SK56198-750	Enclosure
SK56198-751	Inner Panel
SK56198-752	
SK56198-753	Box Elect. Controls Instc.
SK56198-754	Hinge Plate Controls
SK56198-755	Elect. Controls Box Assy
SK56198-756	I.D. Selector Plate
SK56198-757	Side Panel - Structure
SK56198-760	Fluid Dispenser
SK56198-761	Injector Drive
SK56198-762	Sleeve
SK56198-763	Driver
SK56198-764	Block Housing
SK56198-765	Switch Plate
SK56198-766	Caniage
SK56198-767	Support Plate
SK56198-768	End Plates

DRAWING LIST (Cont'd)

SK56198-769	Drive Screw
SK56198-770	Accumulator Assy
SK56198-771	Piston Accumulator Assy
SK56198-772	Cap Accumulator Assy
SK56198-774	Pump Assy
SK56198-775	Rotor Assy
SK56198-776	Base Assy, Pump
SK56198-777	Fittings, Pump
SK56198-778	Rotor, Pump
SK56198-779	Details, Pump
SK56198-780	Volume Reduction Compit
SK56198-781	Door Assy
SK56198-782	M'tg Plate
SK56198-783	Side Enclosure
SK56198-784	Details
SK56198-785	Pressure Plate Lower
SK56198-786	Side Panel, Door Assy
SK56198-787	Door Panel
SK56198-788	Door Lift
SK56198-789	Details Door Assy

7.2.2 Electrical

ER47D220980	Urine Subsystem Electrical Schematic
ER47D220981	Urine Subsystem Wiring Diagram
ER47D220982	Urine Subsystem Power Distribution
ER47D220983	Urine Subsystem Block Diagram
SK56198-790	Urine Subsystem Control Block Diagram

7.3 Operating Instructions

The Urine Subsystem Operating Model represents a fully automated approach to urine collection, volume measurement and sampling. Subsystem operation requires the following user actions prior to and during use.

7.3.1 Set-up

7.3.1.1 Installation

a. Connect to 28 VDC supply (including ground).

b. Connect to water supply (15 to 40 psig).

c. Connect dump port to waste drain (or equal).

d. Fill biocide reservoir (300 ml of a 30% solution of Betadine).

e. Connect printer.

7.3.1.2 Check-out

a. Install sample containers.

b. Cycle the system thru the normal operation sequences (See 7.3.2 Below); use about 250 to 300 ml of water to simulate a micturition. Note: The volume recorded on the printer will be in error by an amount equivalent to the subsystem residual, assuming the subsystem is completely free of liquid at start of check-out.

c. Check calibration by injecting known quantities of fluid and comparing with the print-out value. Fluid sample preparation by weight is recommended. If recalibration is required, proceed as in 7.3.4 below.

7.3.2 Normal Operation

7.3.2.1 Power ON

a. Actuate power ON switch. Note: Mission time starts at this action.

7.3.2.2 Collect, Measure, Sample

a. Install sample containers (the subsystem will not operate unless at least one sample container [24-hour pool] is in place).

b. Set subject ID selector switch via the reset position.

c. Actuate START switch (See Table 7.3-1).

d. Remove urinal and micturate into urinal.

e. When micturition complete, replace urinal. If urinal hose not fully elevated, as when used in a standing position, elevate hose momentarily to ensure that all the urine enters the phase separator (this action not required when operating in a zero gravity environment).

f. After urinal is replaced, actuate "SAMPLE" switch (See Table 7.3-1). Remaining operation is automatic; when SAMPLE switch indicator light OFF, subsystem ready for next user.

g. If installed, remove microbiological and chemical sample containers.

7.3.2.3 Small Sample

a. Remove chemical sample container and install 24-hour pool container in its place.

b. Actuate SMALL SAMPLE switch (See Table 7.3-1).
Remaining operation is automatic; when SMALL SAMPLE switch indicator light OFF, subsystem ready for next user.

7.3.2.4 Volume Reduction

a. At end of each 24-hour mission time period, remove installed 24-hour pool containers.

b. Insert a used container into the volume reduction assembly compartment.

c. Close the compartment door and actuate the VOLUME REDUCTION switch (See Table 7.3-1).

TABLE 7.3-1 DISPLAY INDICATION

SWITCH	INDICATOR LIGHT	SUBSYSTEM CONDITION
1. POWER ON	Solid	Power on, normal
2. START	Solid	Normal operation
	Flashing	Phase Separator rpm low; dispenser not in recirculate position; subject ID not selected via reset position
3. SAMPLE	Solid	Normal operation
	Flashing	24-hour pool container not in place; urinal not replaced;
4. SMALL SAMPLE	Flashing	Indicates use small sample sequence
	Solid	Normal operation
5. VOLUME REDUCTION	Solid	Normal operation
6. DISINFECT	Solid	Normal operation
	Flashing	Urinal not in position

d. When VOLUME REDUCTION switch indicator light OFF, remove sample container.

e. Repeat for each used 24-hour pool container.

7.3.2.5 Disinfect

a. Actuate DISINFECT switch. Remaining action is automatic; when DISINFECT switch indicator light OFF, subsystem ready for normal use.

7.3.3 Emergency Operation

a. Open valve V5.

b. Remove urinal and micturate. Note: The dump outlet must be connected to a below ambient pressure sink during emergency operation.

c. Replace urinal and close valve V5.

7.3.4 Calibration

a. Actuate power ON switch.

b. Install sample containers as required and set subject ID switch.

c. Actuate START switch.

d. Inject 50 grams of water into the urinal. Elevate the urinal to insure all of the water enters the phase separator.

e. Adjust output of the pressure sensor to trigger the SMALL SAMPLE switch cut-off (with the 50 grams in the phase separator).

f. Add additional water and actuate the SAMPLE switch (to complete the sequence).

g. Using the operation sequence 7.3.2.2 (b thru f) above, inject 300 grams of water into the phase separator via the urinal. Compare with the recorded output on the printer and adjust the proportional sampling cut-off value up or down as required.

h. Repeat (e) above as required until printer value agrees with the input value.

i. Check calibration up to 1000 grams as in 7.3.1.2 (c). Repeat (e) and (f) above if required.

7.4 Component Data Sheets

Component data sheets for major purchased items are included in this section in the following order:

1. Phase Separator Motor/Tach. Generator (Inland Motor Corp.)
2. Blower (Rotron Mfg. Co., Inc.)
3. Planetary Gear Motors (Globe Industries)
4. Gear Pump (Micropump Corp)
5. Cooling Compartment Fan (Globe Industries)
6. Thermoelectric Elements (Cambion)
7. Pressure Sensor (Setra Systems, Inc.)
8. Optoelectronic Sensor (Texas Instruments)

TYPE NO.

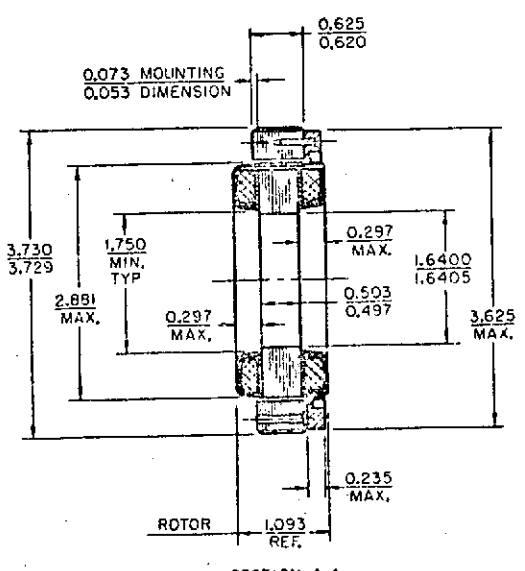
0.85 lb-ft

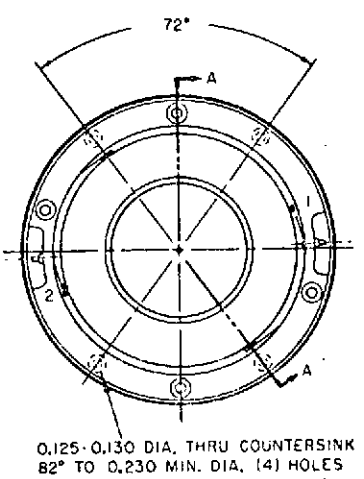
MOTOR SIZE CONSTANTS	UNITS	SYMBOL	VALUE
Peak torque	lb-ft	T_P	0.85
Motor constant	lb-ft/$\sqrt{watt}$	K_M	0.097
Electrical time constant	milli-sec	$\tilde{T}_E$	1.6
Mechanical time constant	milli-sec	$\tilde{T}_M$	17.7
Power input, stalled, at peak torque (25°C)	watts	P_P	77
Viscous damping coefficients: Zero impedance source	lb-ft/rad/sec	F_O	0.013
Infinite impedance source	lb-ft/rad/sec	F_I	0.5×10^{-3}
Motor friction torque	lb-ft	T_F	0.013
Ripple torque, average to peak	percent	T_R	5
Ripple cycles per revolution	cycles/rev	—	41
Ultimate temperature rise per watt	deg C	TPR	5.0
Max permissible winding temperature	deg C	—	105
Rotor moment of inertia	lb-ft-sec²	J_M	2.3×10^{-4}
Max power rate	lb-ft/sec²	$\dot{P}$	3100
Max theoretical acceleration	rad/sec²	α_M	3700
Max no load speed	rad/sec	ω_{NL}	67
Motor weight	lb	—	1.5

The motor winding constants shown here are typical and are not meant to indicate the complete range available. For information on motor windings not shown please contact your local representative or the factory.

The type T-2955 is a frameless DC permanent magnet torque motor. It is shipped as three unmounted components — rotor, brush ring, and permanent magnet field. When installed, it is required that the structure with which the circumferentially oriented field is in direct contact must be non-magnetic. The rotor-to-field eccentricity should not exceed 0.004 inches. See installation section for detailed installation instructions and specific precautions. Brush life will normally exceed 10^7 revolutions. Rotor hubs and field adapters are supplied to customer specifications.

WINDING CONSTANTS	UNITS	SYMBOL	WINDING DATA FOR MODELS T-2955-A THRU T-2955-H							
			A	B	C	D	E	F	G	H
DC resistance (25°C)	ohms	R_M	1.8	2.7	6.7	10.3	16.2	41.7	105	170
Volts at peak torque (25°C)	volts	V_P	12.2	14.9	22.8	28.2	34.5	56.7	89.2	114
Amps at peak torque	amps	I_P	6.8	5.5	3.4	2.74	2.13	1.36	0.85	0.67
Torque sensitivity	lb-ft/amp	K_T	0.125	0.155	0.25	0.31	0.40	0.63	1.0	1.27
Back EMF	volts/rad/sec	K_B	0.17	0.21	0.34	0.42	0.54	0.85	1.36	1.73
Inductance	milli-hys.	L_M	2.7	4.1	11	17	27	68	0.18	0.28





TACHOMETER GENERATOR TYPE NO. TG-2916

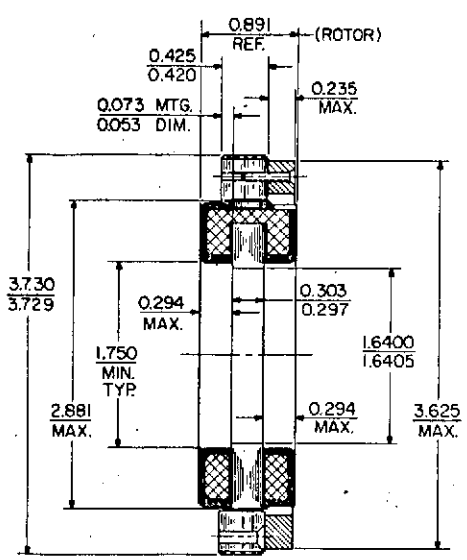
0.89* volts/rad/sec (max.)

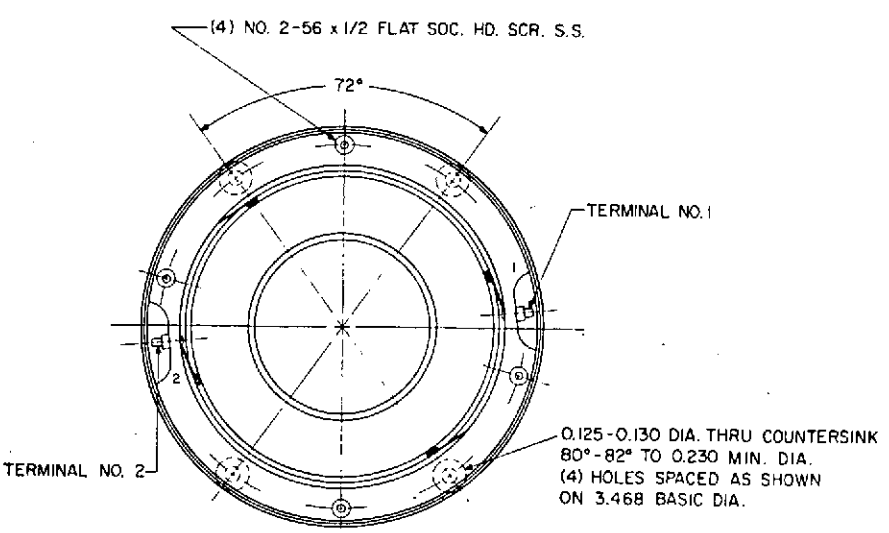
The type TG-2916 is a frameless DC permanent magnet tachometer generator. It is shipped as three unmounted components — rotor, brush ring, and permanent magnet field (stator) with keeper. This keeper must not be removed until rotor is fully in place. When installed, it is required that the structure with which the circumferentially oriented field is in direct contact, be non-magnetic. Rotor to field eccentricity should not exceed 0.002 inches. See installation section for detailed installation instructions. Commutator is gold-plated; brushes are of silver graphite. Brush life will normally exceed 10^8 revolutions. Rotor hubs and field adapters are supplied to customer specification.

TACHOMETER GENERATOR SIZE CONSTANTS	UNITS	SYMBOL	VALUE
Tach generator friction torque	lb-ft	T_F	0.014
Ripple voltage, average to peak	percent	E_R	2.0
Ripple cycles per revolution	cycles/rev	—	71
Rotor moment of inertia	lb-ft-sec²	J_M	2.1×10^{-4}
Tach generator weight	oz	—	17.5

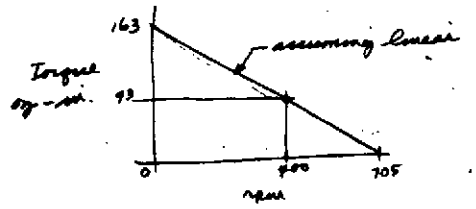
TACHOMETER GENERATOR WINDING CONSTANTS	UNITS	TOL	SYMBOL	WINDING DATA FOR MODEL TG-2916					
				A*	B	C*	D	E	F
DC resistance (25°C)	ohms	±12.5%	R_T	265	41.5	420			
Voltage sensitivity	volts/rad/sec	±10%	K_G	0.71	0.28	0.89			
Inductance	henries	±30%	L_M	0.032	0.005	0.051			
Min load resistance	ohms	nom	$R_{L\,(min)}$	25K	4K	42K			
Max operating speed	rad/sec	nom	ω_{max}	150	380	119			
Volts @ max operating speed	volts	nom	V_{max}	106	106	106			

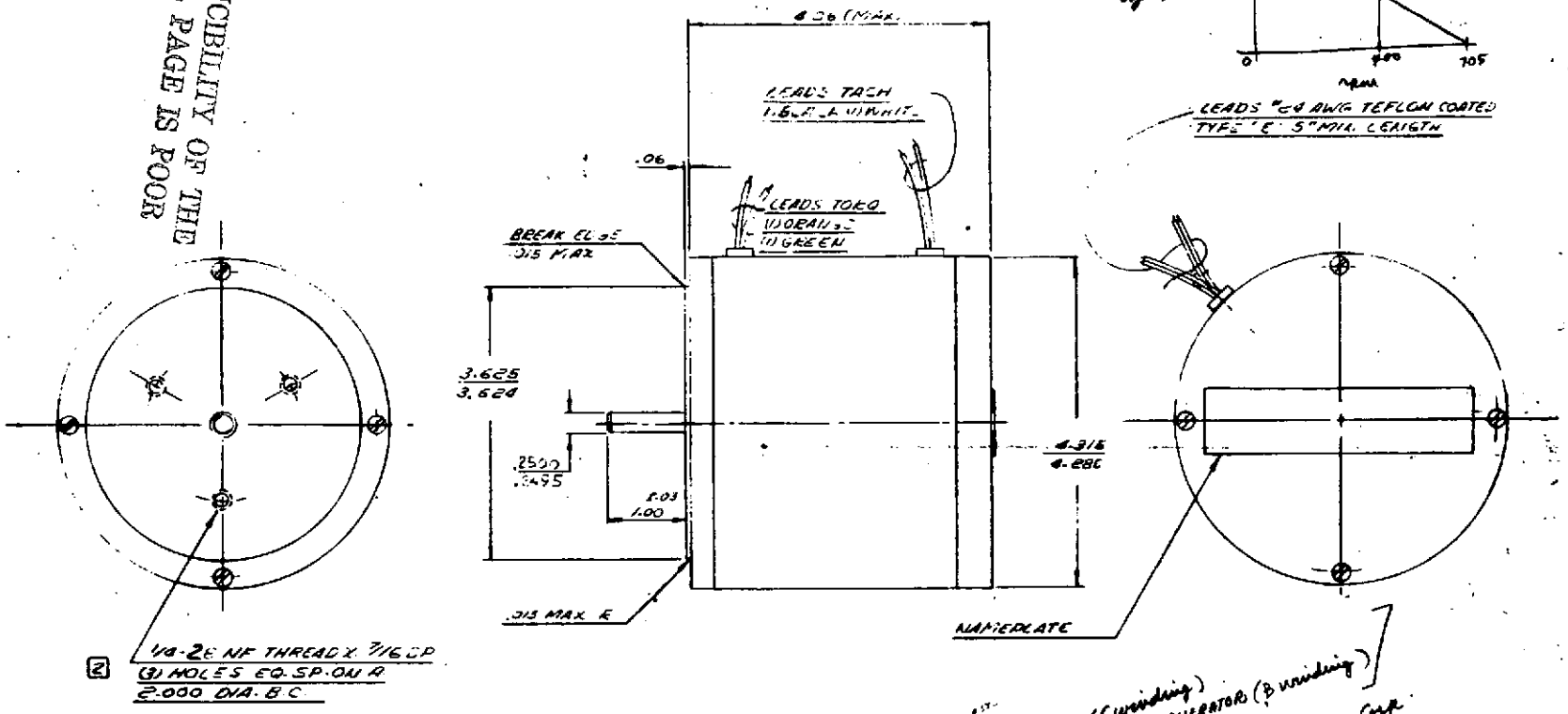
*Special Winding





DO NOT SCALE DWG. USE DIMENSIONS ONLY. ALL DIMENSIONS ARE INCHES UNLESS OTHERWISE SPECIFIED. UNLESS OTHERWISE SPECIFIED X = ±.010, XX DEC. PLACES = ±.005, ANG. = ±1°. UNLESS OTHERWISE SPECIFIED REMOVE ALL BURRS AND BREAK ALL SHARP EDGES. SIZE C. DWG. NO. 21450. REV. T





LEADS #24 AWG TEFLON COATED TYPE "E" 5" MIN. LENGTH

NOTES:

1. WITH A POSITIVE VOLTAGE APPLIED TO THE "GREEN" LEAD, ROTATION SHALL BE C.C.W. AS VIEWED FROM THE SHAFT END.
2. WITH A C.C.W. ROTATION OF E0TORS A POSITIVE VOLTAGE SHALL BE GENERATED ON THE "BLACK" LEAD.
3. MAX SHAFT RUNOUT TO BE (.002 TIR) WHEN MOUNTED.

T-2955 MOTOR (C winding)
TG-2916 TACHOMETER GENERATOR (B winding)
checked these data with Josh Inrhune at Inland Motor Corp
8-372-7011
(703) 639-3973

DELETED BY WIRE TO AMENDING - (illegible) #6675

EM-1802

MATERIAL	HEAT TREAT	FINISH
NONE	NONE	BLACK ANODIZE

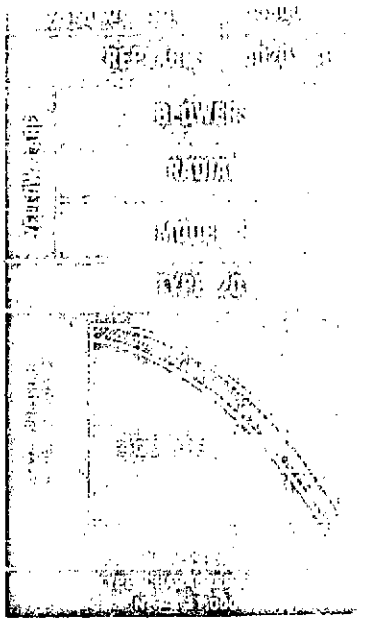
INLAND MOTOR CORP. OF VIRGINIA
1901 FIRST STREET
RADFORD

OUTLINE
TT-2911

SCALE: 1-1 PART LIST NO.

SIZE C DWG. NO. 21450 REV. T

- HIGH PRESSURE-TO-VOLUME RATIO
- SIZE: 3½" x 3 5/16" x 4 13/32" APPROX. • WEIGHT: 1.7 LBS.
- 400 CPS, 1 PHASE OR 3 PHASE, 115 OR 200 VOLTS
- MULTIPLE MOUNTING ARRANGEMENTS
- BUILT TO APPLICABLE MILITARY SPECIFICATIONS



MODEL R/201

WHERE TO USE

The Model R Type 201 blower is a single-stage, radial-wheel blower with a specific speed characteristic of 11,000. It is consequently recommended where a high pressure-to-volume ratio is required and where small physical size and light weight is essential. It is, therefore, ideally suited for airborne applications where high shaft speeds may be obtained from the aircraft's 400 CPS power source. The most important current application is in a cargo compartment smoke detection system aboard commercial transport aircraft. For lower pressure-to-volume ratios, see Rotron Model D centrifugal blowers or, where pressures higher than those obtainable with the Model R Type 201 are mandatory, refer to Rotron's larger Model R Type 3501, Model M and Model L multistage blowers.

ADAPTORS AND MOUNTING

The Model R Type 201 blower may be fitted with a nozzle type inlet rim suitable for a simple hose connection. The outlet flange can be attached to any flat surface or cabinet wall.

Mounting may be accomplished from the blower outlet flange or from mounting flats at the top and bottom of the motor. On request the inboard motor endbell can be tapped to offer a fourth mounting alternative.

MOTOR

The induction motor is either three-phase or permanent split-phase capacitor type and is available with either A, F, or H insulation. The black enameled case, which totally encloses the motor, is finned for maximum heat dissipation resulting in a minimum winding temperature rise. The motor operates on double-shielded, precision ball bearings which are greased for life and are carefully aligned for quiet, trouble-free operation. The case and shaft are of die-cast aluminum and stainless steel respectively. A compact screw-type terminal block is fitted integrally into a recess in the motor case so that hookup cables can be run directly to the motor. Motors meet applicable military specifications for ground, sea and airborne service. See applicable Catalog Sheet in Section C, "MOTORS." U. S. Patent Design 174,148. Other U. S. Patents Pending.

ROTATION AND BLAST

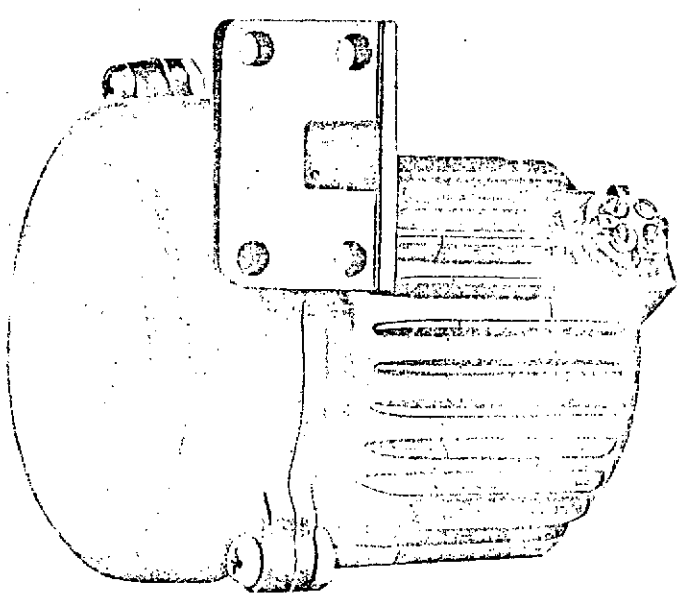
The Type 201 blower is supplied for CCW rotation only. Direction of blast, however, may be rotated at 90° increments to any of four possible choices. The drawing that follows shows a 3 o'clock blast.

MATERIALS AND FINISH

The blower housing consists of a two-piece aluminum casting anodized and finished in dull black. The blower wheel is aluminum and anodized. The motor case and shaft are of die-cast aluminum and stainless steel respectively. The motor case has a black enameled finish. All finishes meet applicable military specifications.

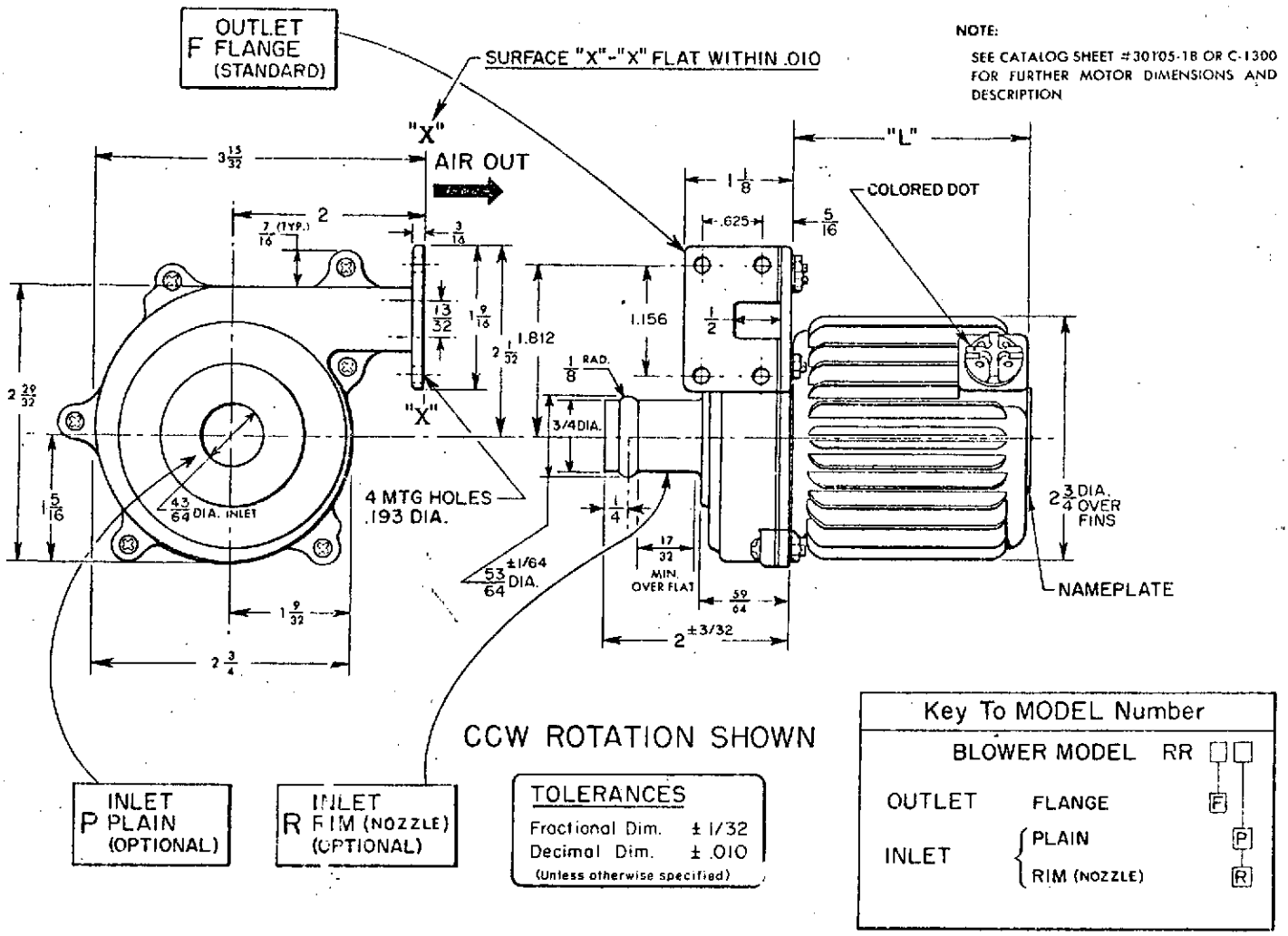
ORDERING INFORMATION

- Select model, type and motor series number from Type Chart.
- Consult Rotron for special inlet, outlet or mounting arrangements.



ROTRON MANUFACTURING CO., INC.
HASBROUCK LANE, WOODSTOCK, N. Y.

4-67-3m



SHAFT SPEED

Figures given in this TYPE CHART as well as on the nameplate are nominal only and generally refer to MAXIMUM CFM air delivery (Maximum Load) at sea level at nominal line voltage and frequency.

HOOKUP

The first suffix letter immediately following the motor SERIES number listed in the accompanying TYPE CHART refers to the applicable wiring diagram found on Catalog Sheet C-1000, Section C, MOTORS. Wiring hook-up is dependent upon motor rotation only.

CAPACITORS

Running capacitors indicated in this TYPE CHART are not normally supplied by Rotron. Their values should preferably be held within a tolerance of ±10%, especially for 400 CPS and variable frequency motors. In selecting capacitors, due attention should be given to variations in capacity ratings with high and low ambient temperatures. Unless otherwise indicated in this TYPE CHART, Working Voltage ratings are 220 VAC for 115 Volt lines and 330 VAC for 230 Volt lines. Oil-impregnated, canned, paper dielectric capacitors are recommended.

THREE PHASE MOTORS

For optimum reliability three phase 3-wire ("J") connections are preferable to three phase 4-wire ("Q") connections where neutral wire is brought out. The source impedance of a three phase power supply may be unbalanced causing circulating currents in the motor windings through the neutral connection. This could lead to overheating and possible motor failure due to causes not attributable to motor design or quality. Also in the event of a temporary line failure (open) the circulating current would be considerably lower in the remaining branches adding a degree of safety under abnormal power supply conditions.

The fourth terminal post on 3-wire ("J") designs is a dummy.

DIMENSIONS

For dimensions and tolerances, refer to the outline drawing.

For details of motor dimensions refer to Catalog Sheet 30105-1B or C-1300 in Section C, Motors.

AIR DELIVERY

Figures in the AIR column of this TYPE CHART represent actual amount of air moved at sea level standard atmospheric conditions per AMCA* code, Bulletin #210. The figures are for free-delivery at no static pressure (P_s). Maximum P_s figures listed in this TYPE CHART apply to complete cut-off or no-delivery state. The CFM and MAXIMUM P_s figures therefore serve only as a preliminary performance guide, and should NOT be construed as indicating that the MAXIMUM CFM figure is obtainable at the MAXIMUM P_s figure.

WATTAGE AND CURRENT

Figures in this TYPE CHART are nominal only, for nominal line voltage and frequency. They are representative of typical production unit tests and must not be construed as maximum or minimum values. In case of variable frequency motors, they apply to 400 CPS. Where more than one voltage is stated, amperage figures apply to the lower voltage.

*AMCA—Air Moving and Conditioning Association, Inc., 205 W. Touhy Ave., Park Ridge, Ill., is the successor to NAFM, National Association of Fan Manufacturers, Inc.

BEARING SHELF LIFE

Rotron military quality motors are built to operate under humidity conditions as specified in MIL-E-5272. When stored under high humidity conditions, however, the bearings will deteriorate. It is therefore strongly recommended that the fans and blowers not be subjected to more than six months of inoperative shelf life in humid climates and not more than one year in dry climates. Units properly packaged in sealed containers with a desiccant may be expected to withstand longer shelf life.

MOTOR INSULATION

This TYPE CHART lists the NEMA classification for electrical insulation. Motors with a different class of insulation may generally be supplied. To obtain the maximum allowable winding temperature for any unit, add the maximum ambient temperature, (°C), to the winding rise temperature obtained from the performance graphs immediately following this page. Limiting total winding temperatures are 105°C for Class A, 155°C for Class F, and 180°C for Class H insulation.

MODEL R BLOWER — TYPE 201

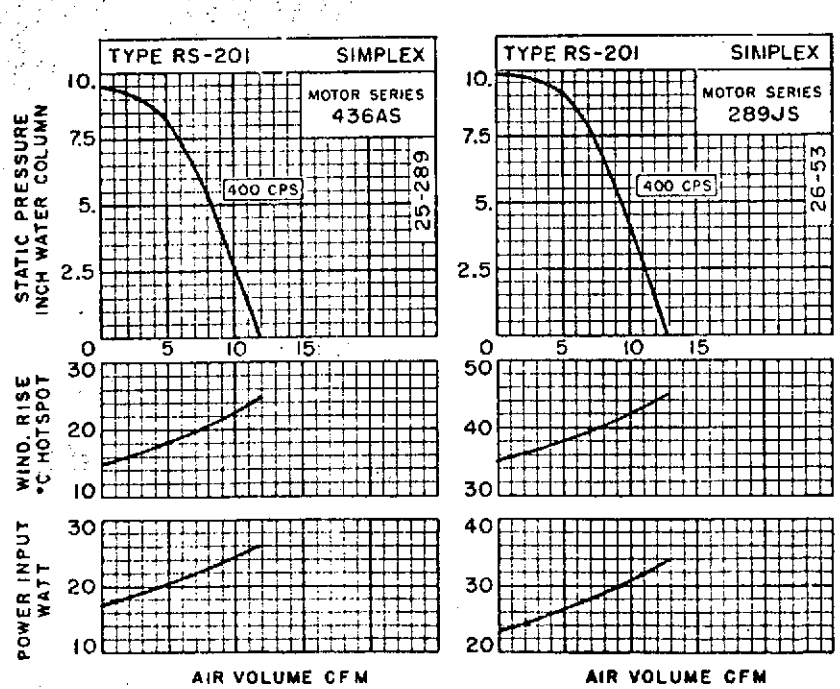
BLOWER	MOTOR		ELECTRICAL									AIR		MECHANICAL	
Type	Frame	Series	Volt	Phase	CPS	Cap.* Mfd.	Nominal RPM	Insul. Class	Full Load Watts	Line Amps. At Lower Volt.	Locked Rotor Amps. At Lower Volt.	Max. CFM	Max. S. P. at No Del.	Approx. Wt. Lbs.	Dimensions "L"
RS-201	TA2	436AS	115	1	400	0.15	19500	H	26	0.23	0.39	12	9.5	1.75	$2\frac{15}{32}$
RS-201	TA1	289JS	200†	3	400	—	21000	H	35	0.13	0.41	13	9.8	1.25	$1\frac{31}{32}$

* Running Capacitors are not normally supplied by Rotron.
† For 3-phase motors all voltages are phase to phase.

ACCURACY

Curves at right represent results of measurement of a typical sample and should be taken as nominal. Rotron will advise tolerance for a specific application. Allowance should be made for the effect of "channeling" of ball bearing grease.

IMPORTANT: Before placing order or requesting a quotation, see Key to Model Number and paragraph "Ordering Information" on this Catalog Sheet for COMPLETE product "call out" information requested.



torque:
Maximum continuous torque—to 300 oz. in. depending upon ratio.

voltage:
6 to 50 v.d.c.

size:
⅞" diameter.

weight:
Gearmotor weighs 5 to 10 ounces depending upon reduction ratio.

gears:
Planetary gearing system. All gears are precision manufactured and heat-treated for consistently reliable performance and life.

backlash:
Varies with reduction but average unit will have less than 3°.

protection:
Housing is cadmium plated to conform to QQ-P-416 Type 2 for protection against moisture, fungus, and salt spray.

bearings:
Output shaft is supported by two double-shielded ball bearings.

shaft:
No. 416 stainless steel passivated per QQ-S-763.

electrical connection:
Two teflon-coated #26 AWG leads on shielded type. Two solder type terminals on open type.

mounting:
Unit is mounted by means of pilot and four holes in flange.

TYPE SS

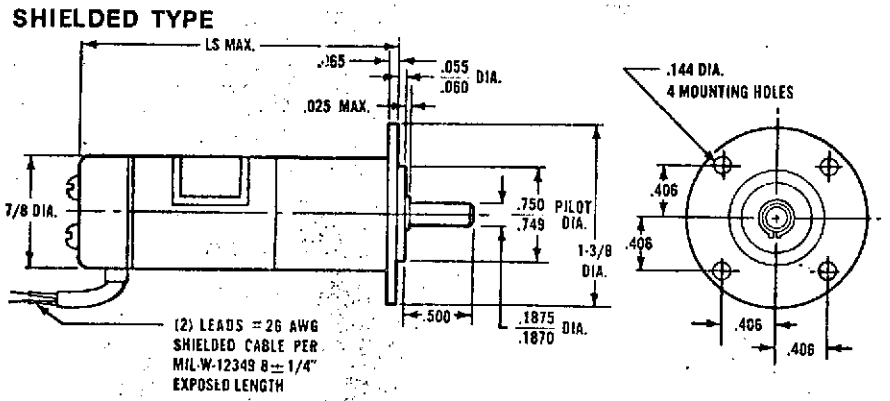
This extremely small size and lightweight gearmotor consists of a Globe Type SS d.c. motor and a system of precision planetary gearing. The combination provides smooth, dependable performance and maximum output torque in the smallest possible space. The design has been predicated on maximum reliability.

Units are only ⅞" in diameter. Overall length ranges from 2 17/64" to 3 11/64", depending on speed reduction ratio. Twenty-one different standard reduction ratios, ranging from 3.82:1 to 36,873:1, are available.

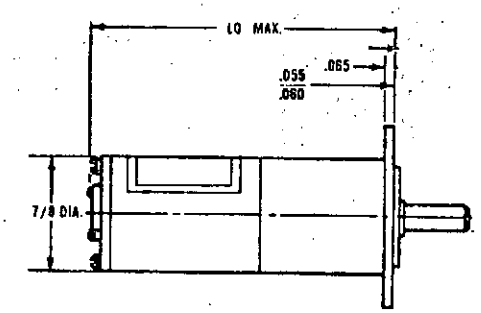
These sub-miniature Globe gearmotors meet all applicable military specifications.

DIMENSIONS

SHIELDED TYPE



OPEN TYPE



Note:
Be sure to check Globe for latest data prior to preparing spec control prints.

GLOBE INDUSTRIES DIVISION OF TRW INC.
2275 Stanley Avenue · Dayton, Ohio 45404
Telephone: 513 222-3741 · TWX: 810 459-1642

STANDARD PART NUMBERS AND DATA

SPEED REDUCTION RATIO	MAXIMUM CONTINUOUS TORQUE (1) (oz. in.)	TORQUE MULTIPLICATION RATIO (2)	STANDARD PART NUMBERS* shielded type dimension LS	shielded type part no.	open type dimension LO	open type part no.
3.82:1	1.0	3.1	2 35/64"	43A197	2 17/64"	43A196
5.77:1	1.5	4.6		43A200		43A199
14.58:1	3.0	9.3		43A140		43A100
22.03:1	4.5	14	2 25/32"	43A141	2 25/32"	43A101
33.28:1	7.0	21		43A142		43A102
55.66:1	10	28		43A143		43A103
84.11:1	14	43		43A144		43A104
127.1:1	21	65	2 61/64"	43A145	2 61/64"	43A105
192:1	30	93		43A146		43A106
321:1	45	130		43A147		43A107
485:1	70	200		43A148		43A108
733:1	100	300	3 1/8"	43A149	3 1/8"	43A109
1108:1	150	450		43A150		43A110
1853:1	200	600		43A151		43A111
2799:1	300	900		43A152		43A112
4230:1	300	1400	3 9/32"	43A153	3 9/32"	43A113
6391:1	300	2100		43A154		43A114
10689:1	300	2800		43A155		43A115
16150:1	300	4200	3 29/32"	43A156	3 29/64"	43A116
24403:1	300	6400		43A157		43A117
36873:1	300	9700		43A158		43A118

(1) This is the maximum continuous output torque rating of a given geartrain. Actual output depends upon the armature winding selected.

(2) Maximum continuous torque of the gearmotor is the product of the multiplication ratio times the rated torque of the motor as given in Bulletin A-1200. This value must not exceed the maximum continuous torque given in the second column, above. Minimum efficiency of the geartrain is the product of the multiplication ratio divided by the speed ratio times 100%.

BASIC MOTOR DATA

VOLTAGE (v.d.c.)	SPEED no load (rpm)	TORQUE max. rated (oz. in.)	TORQUE stall (oz. in.)	CURRENT gearmotor max. no load (amps)	CURRENT max. rated load (amps)	CURRENT max. stall (amps)	ARMATURE DASH NO.*
6	11,000-13,500	0.28	1.6	.580	1.00	3.6	–17
6	8,500-11,000	0.38	1.3	.470	1.00	2.2	–16
12	13,500-17,000	0.22	2.0	.340	.54	2.6	–15
12	10,000-13,000	0.33	1.7	.265	.54	1.5	–14
27	17,000-20,000	0.17	2.9	.190	.26	1.9	–13
27	15,000-18,000	0.20	2.5	.170	.24	1.4	–12
27	12,000-15,000	0.25	2.0	.140	.24	1.15	–1
27	10,000-13,000	0.31	1.6	.120	.23	0.78	–2
27	8,500-10,500	0.45	1.3	.095	.23	0.48	–3
27	6,500- 9,000	0.45	1.0	.090	.20	0.29	–4
27	5,500- 7,500	0.36	0.82	.070	.15	0.21	–5
50	10,000-13,000	0.32	0.97	.065	.13	0.22	–7
50	8,500-10,500	0.42	1.20	.055	.13	0.35	–6
50	6,000- 7,500	0.38	0.80	.040	.09	0.12	–9

Orange blocks indicate units not normally stocked by Globe distributors.

WHEN YOU ORDER

***Part Number.** Units described above are standard and may be ordered by part number. Complete part number consists of basic part number plus an armature dash number to designate armature voltage and speed.

For accessories and modifications, see introduction to this catalog section, page 7.

torque:
Up to 300 oz. in. maximum continuous torque.

voltage:
6 to 50 v.d.c.

size:
¾" diameter.

weight:
4 to 9 oz., depending on ratio.

gears:
Planetary gearing system. All gears are precision manufactured and heat-treated for consistently reliable performance and life.

backlash:
Varies with ratio but will have less than 3°.

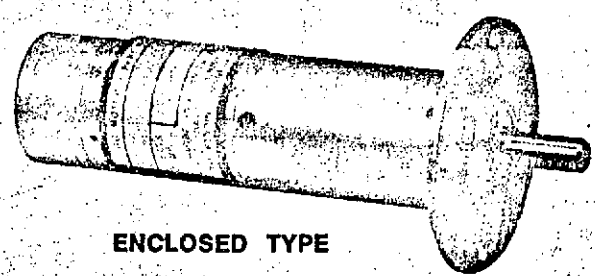
bearings:
Output shaft is supported by two double-shielded, life-lubricated ball bearings.

electrical connection:
Solder terminals are provided on open type. 8" leads on enclosed type.

mounting:
Unit is mounted by pilot and four holes in flange.

GLOBE INDUSTRIES DIVISION OF TRW INC.
2275 Stanley Avenue · Dayton, Ohio 45404

TYPE SD



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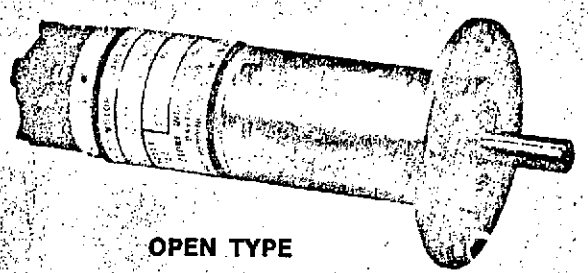


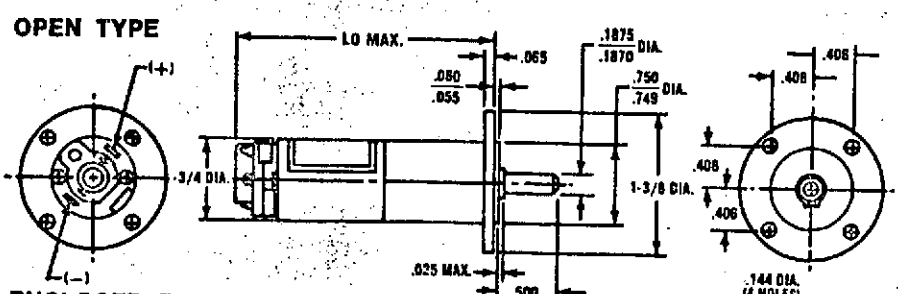
OPEN TYPE

This small size, light weight gearmotor is comprised of Globe's ¾" Type SD motor, Bulletin A-1200N coupled with a precision planetary gear train. The combination provides smooth, dependable performance and maximum output torque in the smallest possible space. It is designed to provide a military quality gearmotor of exceptionally compact size.

Nineteen different reduction ratios, ranging from 3.82:1 to 36,873:1, are available. These subminiature Globe gearmotors are designed to meet the applicable environmental specifications of MIL-M-8609.

DIMENSIONS

OPEN TYPE



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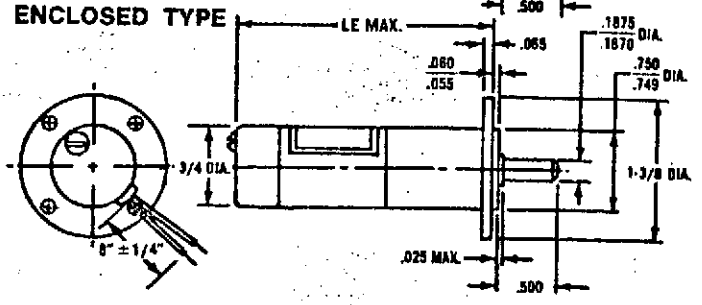


Note:
Be sure to check Globe for latest data prior to preparing spec control prints.

STANDARD PART NUMBERS AND DATA

SPEED REDUCTION RATIO	MAXIMUM CONTINUOUS TORQUE (1) (oz. in.)	TORQUE (2) MULTIPLICATION RATIO	LO MAX.	LE MAX.	STANDARD PART NUMBERS * open type	STANDARD PART NUMBERS * enclosed type
3.82	1.0	3.1	2 3/8"	2 13/32"	168A247	168A249
5.77	1.5	4.6			168A248	168A250
14.58	3.0	9.3			168A204	168A223
22.03	4.5	14	2 39/64"	2 41/64"	168A205	168A224
33.28	7.0	21			168A206	168A225
55.66	10	28			168A207	168A226
84.11	14	43			168A208	168A227
127.1	21	65	2 25/32"	2 13/16"	168A209	168A228
192	30	93			168A210	168A229
321	45	130			168A211	168A230
485	70	200			168A212	168A231
733	100	300	2 61/64"	2 63/64"	168A213	168A232
1108	150	450			168A214	168A233
1853	200	600			168A215	168A234
2799	300	900			168A216	168A235
4230	300	1400	3 1/8"	2 5/32"	168A217	168A236
6391	300	2100			168A218	168A237
10689	300	2800			168A219	168A238
16150	300	4200			168A220	168A239
24403	300	6400	3 19/64"	3 21/64"	168A221	168A240
36873	300	9700			168A222	168A241

(1) This is the maximum continuous output torque rating of a given geartrain. Actual output depends upon the armature winding selected. See Bulletin A-1200N, Type SD motors, for rated torque of various armatures.

(2) Maximum continuous output torque of the gearmotor is the product of the multiplication ratio times the rated torque of the motor as given below. This value must not exceed the maximum continuous torque given in the second column, above. Minimum efficiency of the geartrain is the product of the multiplication ratio divided by the speed ratio times 100.

Orange blocks indicate units not normally stocked by Globe distributors.

BASIC MOTOR DATA

VOLTAGE (v.d.c.)	SPEED no load (rpm)	TORQUE max. rated (oz. in.)	TORQUE nominal stall (oz. in.)	CURRENT max. no load (amps)	CURRENT max. rated load ** (amps)	CURRENT nominal stall (amps)	ARMATURE DASH NO.*
6	14,500-17,500	0.20	1.50	.460	0.78	3.6	-17
6	12,000-14,000	0.28	1.20	.380	0.78	2.2	-16
6	9,000-10,500	0.32	0.90	.270	0.60	1.4	-15
12	13,000-15,500	0.22	1.60	.220	.38	1.50	-14
12	9,500-11,000	0.37	0.80	.155	.37	0.93	-13
12	8,500-10,000	0.25	0.60	.135	.26	0.70	-12
27	15,500-18,500	0.17	1.80	.110	.17	1.15	-1
27	13,000-16,000	0.22	1.50	.100	.17	0.85	-2
27	10,000-12,500	0.31	1.20	.080	.17	0.48	-3
27	9,000-10,500	0.31	0.90	.065	.14	0.30	-4
27	7,000- 8,500	0.24	0.80	.055	.08	0.21	-5
50	13,000-15,500	0.26	0.90	.050	.10	0.22	-7
50	11,500-13,500	0.31	1.10	.045	.10	0.26	-6
50	11,000-13,000	0.26	0.75	.040	.08	0.18	-8
50	8,000- 9,500	0.18	0.50	.032	.05	0.08	-9
50	7,000- 8,300	0.15	0.45	.028	.04	0.07	-10
50	5,500- 6,500	0.11	0.35	.023	.03	0.05	-11

**GEARMOTOR NO LOAD CURRENT

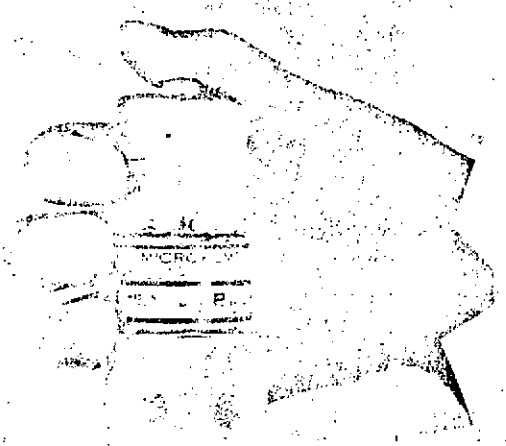
WHEN YOU ORDER

***Part Number.** Units shown above are standard and may be ordered by part number. Complete part number consists of the basic part number plus a dash number to designate armature voltage and speed. Consult Globe for other voltages and variations for special applications.

For accessories and modifications, see introduction to this catalog section, page 7.

MICRO

BULLETIN NUMBER 600



MODEL 8034

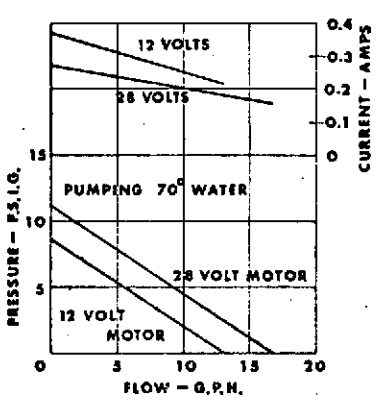
U. S. PATENTS 3,238,883 3,239,870

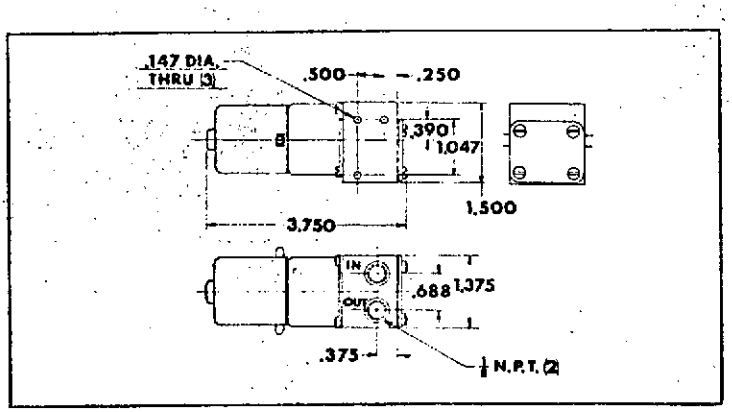
SEAL-LESS miniature GEAR PUMP

HERE IS A MINIATURE GEAR PUMP DESIGNED TO HANDLE A VARIETY OF FLUIDS IN APPLICATIONS WHERE WEIGHT AND SPACE ARE CONSIDERATIONS. BECAUSE THE PUMP IS MAGNETICALLY COUPLED, IT CANNOT LEAK, IT RUNS COOL AND QUIET, AND IS CONTAMINATION FREE. THE 12 VDC (OR 28 VDC) MOTOR ENABLES THE MICROMITE TO PERFORM VARIABLE METERING DUTY. THERE ARE MANY APPLICATIONS IN FILM PROCESSING AND VARIOUS OTHER INSTRUMENTATION WHERE THIS LITTLE PUMP CAN REPLACE A LARGER, MORE CUMBERSOME PUMP. MICROMITE SAVES WEIGHT, SPACE AND EXPENSE.

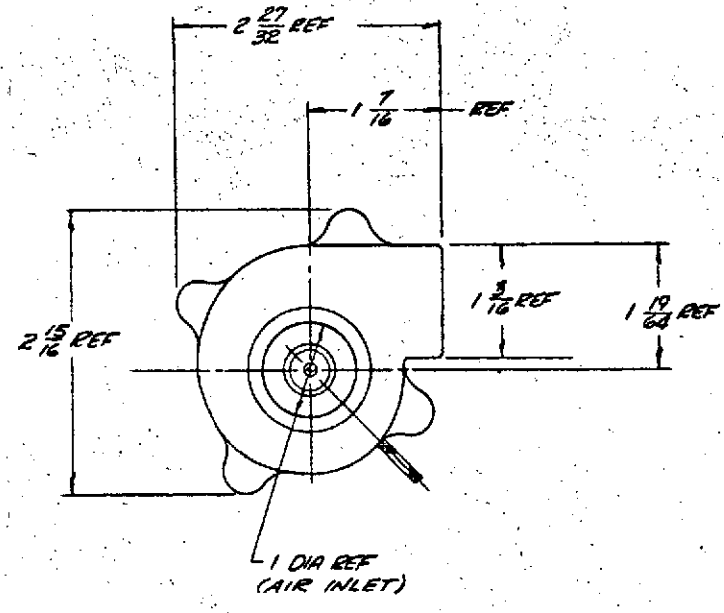
PUMP SPECIFICATIONS
• POLYPROPYLENE OR DELRIN
• CERAMIC (BARIUM FERRITE)
• STAINLESS STEEL
• VITON
• SELF CONTAINED CHECK VALVE

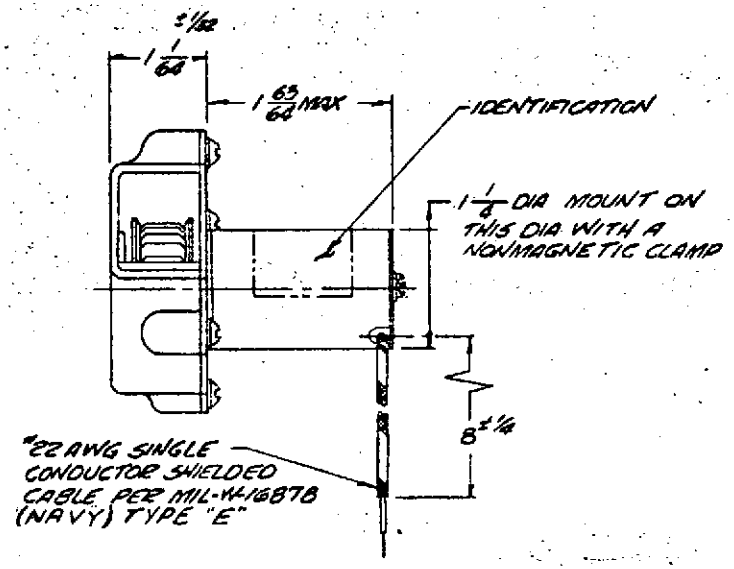
MOTOR SPECIFICATIONS
• 12 VDC OR 28 VDC
• VARIABLE SPEED BY VOLTAGE INPUT
• CHANGEABLE BRUSHES
• CURRENT DRAW – 7 WATTS DC MAX.
• PUMP/MOTOR WEIGHT – 6 OUNCES





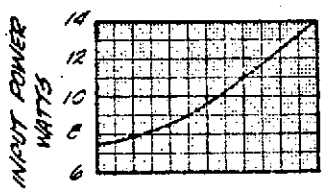
MICRO

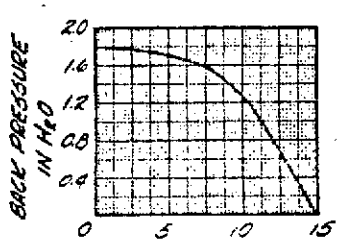




19A1860

NOTES:
1. SPEED: 10,500 RPM MIN AT 27 VDC & NORMAL RATED LOAD.
2. NORMAL RATED LOAD: IMPELLER.
3. DUTY CYCLE: CONTINUOUS.
4. MAX CURRENT: 0.550 AMP AT NORMAL RATED LOAD.
5. OPERATING VOLTAGE: 24 TO 29 VDC.
6. WHEN SHIELDED LEAD IS CONNECTED TO POSITIVE (+) VOLTAGE AND SHIELDING IS CONNECTED TO GROUND (-), ROTATION IS CLOCKWISE VIEWING IMPELLER END.





REDUCED PRINT
ISSUED C/A
MAR 27 1967
JUL 29 [illegible]

-12-

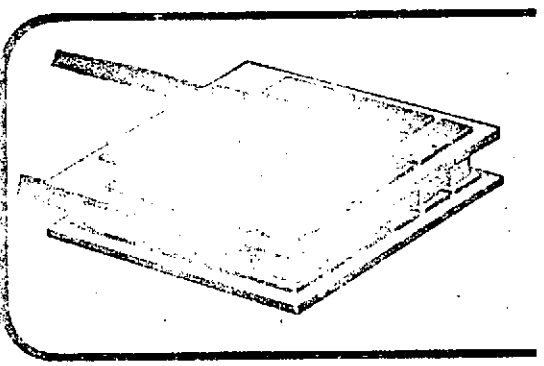
ITEM	REQD	PART NO.	DESCRIPTION	UNIT WT	NEXT ASSY	USED ON
			LIST OF MATERIAL		STANDARD APPLICATION	

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON FRACTIONS ± 1/64 DECIMALS ± .005 ANGLES ± 1°	DFM CEN 23209 STD 7-7-66 FIN. 7-7-66 CHK [illegible] DATE 3-22-67 ENGR E. Wolfe 3-23-67 APPD JHS 3/23/67 APPD	NAME FAN, CENTRAFUGAL-DC, MM, SHLD, 35-125 ARM 1½" BLOWER, PLASTIC SHROUD	GLOBE INDUSTRIES, INC. DAYTON, OHIO
MATL 20A1860 HEAT TREAT COATING	SCALE 2:1 WT		DWG NO. 19A1860 CODE 25140 SHEET 1 OF 1

DO NOT SCALE DRAWING.
GLOBE IND., INC. SHOP STD 53 & 100 SUPPLEMENTS THIS DRAWING.
SPECS REFERENCED ON THIS DRAWING TO BE OF LATEST ISSUE.

MODEL
801-3959-01

CERAMIC MODULE

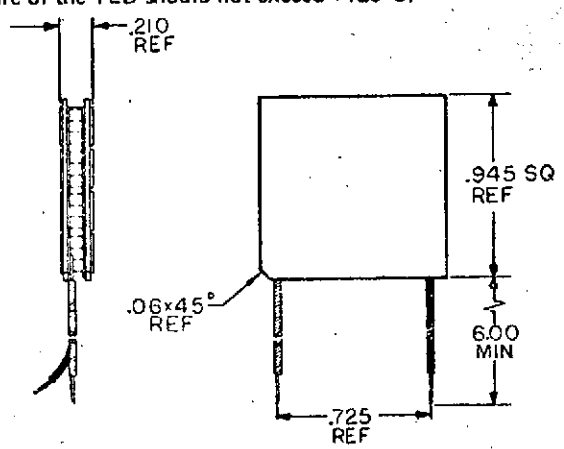


CAMBION's Model 3959-01 is of similar ceramic construction to Model 3958-01. The convenient size and thermal characteristics of Model 3959-01 are desirable for a wide range of instrument applications.

Model 3959-01 yields a high heat pumping capacity of 9.0 watts at a temperature differential of 0°C. With the hot side (Th) at 27°C, a temperature differential of 58°C may be attained by this device in a normal ambient condition. Model 3959-01 is the ceramic equivalent of Model 3954-01.

GENERAL CHARACTERISTICS

Minimum ΔT: 58°C; I = 9 amperes, V = 2.0 dc volts, Ts = 27°C.
Includes all thermal interface drops at mounting surfaces.
Qc: I = 9 amperes, V = 1.9 dc volts, Ts = 27°C, 9 watts (30.7 BTU's/hour)
ΔT = 0°C.
Electrical (AC) Resistance: Not to exceed 220 milliohms at 27°C.
Dielectric withstanding voltage: 500 VDC.
Size .95" x .95" x 0.210 $\pm^{.000}_{.005}$
Weight: 15 Grams
The temperature of the TED should not exceed +125°C.



See Tabulated Data Chapter II.

REFRIGERATING AND HEAT PUMP, EFFECTS OF 3959-01

TH = 30.0 C DT = 56.0 C

I	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
V	0.5	0.7	0.9	1.1	1.2	1.4	1.6	1.8	2.0	2.2
P	0.5	1.4	2.7	4.3	6.2	8.6	11.3	14.3	17.7	21.5
QH(O)	- 3.7	- 1.6	0.8	3.3	5.9	8.8	11.8	15.0	18.4	22.0
QC(I)	- 4.2	- 3.0	- 1.9	- 1.0	-0.3	0.2	0.6	0.7	0.7	0.5
COPR	-802	-210	-71	-23	-4	2	4	5	3	2
COPH	-702	-110	28	76	95	102	104	105	103	102

TH = 30.0 C DT = 60.0 C

I	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
V	0.5	0.7	0.9	1.1	1.3	1.4	1.6	1.8	2.0	2.2
P	0.5	1.4	2.7	4.3	6.3	8.6	11.3	14.4	17.8	21.6
QH(O)	- 4.1	- 2.0	0.3	2.8	5.5	8.3	11.3	14.5	17.9	21.4
QC(I)	- 4.6	- 3.4	- 2.4	- 1.5	-0.8	-0.3	-.0	0.1	.1	-0.1
COPR	-852	-236	-88	-35	-13	-3	0	0	0	0
COPH	-752	-136	11	64	86	96	99	100	100	99

TH = 30.0 C DT = 60.8 C

I	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
V	0.5	0.7	0.9	1.1	1.3	1.4	1.6	1.8	2.0	2.2
P	0.5	1.5	2.7	4.3	6.3	8.7	11.3	14.4	17.8	21.6
QH(O)	- 4.2	- 2.1	0.2	2.7	5.4	8.2	11.2	14.4	17.8	21.3
QC(I)	- 4.7	- 3.5	- 2.5	- 1.6	- 1.0	-0.5	-0.1	.0	-.0	-0.2
COPR	-861	-241	-91	-37	-15	-5	-1	0	0	-1
COPH	-761	-141	8	62	84	94	98	100	99	98

TH = 40.0 C DT = 0.0 C

I	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
V	0.2	0.4	0.7	0.9	1.1	1.3	1.5	1.9	2.0	2.2
P	0.2	0.9	2.0	3.5	5.5	7.9	10.8	14.1	17.8	22.0
QH(O)	2.2	4.6	7.2	10.0	13.1	16.3	19.8	23.5	27.5	31.6
QC(I)	2.0	3.7	5.2	6.5	7.6	8.4	9.1	9.5	9.7	9.6
COPR	889	419	263	184	137	106	84	67	54	43
COPH	989	519	363	284	237	206	184	167	154	143

TH = 40.0 C DT = 4.0 C

I	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
V	0.2	0.5	0.7	0.9	1.1	1.3	1.5	1.8	2.0	2.2
P	0.2	0.9	2.0	3.6	5.6	8.0	10.8	14.1	17.9	22.0
QH(O)	1.7	4.1	6.7	9.5	12.6	15.8	19.3	23.0	26.9	31.0
QC(I)	1.5	3.2	4.7	6.0	7.0	7.8	8.5	8.9	9.0	9.0
COPR	612	346	230	166	125	98	78	62	50	40
COPH	712	446	330	266	225	198	178	162	150	143

TH = 40.0 C DT = 8.0 C

I	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
V	0.3	0.5	0.7	0.9	1.1	1.3	1.6	1.8	2.0	2.2
P	0.3	1.0	2.1	3.7	5.6	8.1	10.9	14.2	17.9	22.1
QH(O)	1.3	3.7	6.3	9.1	12.1	15.3	18.8	22.5	26.3	30.4
QC(I)	1.0	2.7	4.2	5.4	6.5	7.3	7.9	8.3	8.4	8.4
COPR	388	261	199	148	114	90	72	58	46	37
COPH	488	361	299	248	214	190	172	158	146	137

TH = 40.0 C DT = 12.0 C

I	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
V	0.3	0.5	0.7	0.9	1.1	1.4	1.6	1.8	2.0	2.2
P	0.3	1.0	2.2	3.7	5.7	8.1	11.0	14.3	18.0	22.1
QH(O)	0.9	3.2	5.8	8.6	11.6	14.8	18.3	21.9	25.8	29.9
QC(I)	0.6	2.2	3.7	4.9	5.9	6.7	7.3	7.6	7.8	7.7
COPR	202	221	170	131	103	82	66	53	43	35
COPH	302	321	270	231	203	182	166	153	143	135

TH = 40.0 C DT = 16.0 C

I	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
V	0.3	0.5	0.7	0.9	1.2	1.4	1.6	1.8	2.0	2.2
P	0.3	1.1	2.2	3.8	5.8	8.2	11.1	14.3	18.0	22.2
QH(O)	0.5	2.8	5.4	8.2	11.2	14.4	17.8	21.4	25.2	29.3
QC(I)	0.1	1.8	3.2	4.4	5.4	6.1	6.7	7.0	7.2	7.1
COPR	46	167	143	115	92	74	60	49	39	32
COPH	146	267	243	215	192	174	160	149	139	132

REFRIGERATING AND HEAT PUMP, EFFECTS OF 3959-01

TH = 40.0 C DT = 20.0 C

I	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
V	0.3	0.5	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2
P	0.3	1.1	2.3	3.9	5.9	8.3	11.2	14.4	18.1	22.2
QH(O)	.0	2.4	4.9	7.7	10.7	13.9	17.3	20.9	24.7	28.7
QC(I)	-0.3	1.3	2.7	3.8	4.8	5.6	6.1	6.4	6.6	6.5
COPR	-36	118	117	99	81	66	54	44	36	29
COPH	13	218	217	199	181	166	154	144	136	129

TH = 40.0 C DT = 24.0 C

I	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
V	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2
P	0.4	1.1	2.3	3.9	5.9	8.4	11.2	14.5	18.2	22.2
QH(O)	-0.4	2.0	4.5	7.3	10.2	13.4	16.8	20.3	24.1	28.1
QC(I)	-0.7	0.8	2.2	3.3	4.3	5.0	5.5	5.8	6.0	5.9
COPR	-201	72	93	84	71	59	49	40	32	26
COPH	-101	172	193	184	171	159	149	140	132	126

TH = 40.0 C DT = 28.0 C

I	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
V	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2
P	0.4	1.2	2.4	4.0	6.0	8.5	11.3	14.6	18.2	22.3
QH(O)	-0.8	1.5	4.1	6.8	9.8	12.9	16.2	19.8	23.6	27.5
QC(I)	- 1.2	0.4	1.7	2.8	3.7	4.4	4.9	5.2	5.3	5.2
COPR	-302	30	70	70	61	52	43	36	29	23
COPH	-202	130	170	170	161	152	143	136	129	123

TH = 40.0 C DT = 32.0 C

I	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
V	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2
P	0.4	1.2	2.4	4.1	6.1	8.5	11.4	14.6	18.3	22.3
QH(O)	- 1.2	1.1	3.6	6.4	9.3	12.4	15.7	19.3	23.0	26.9
QC(I)	- 1.6	-.1	1.2	2.3	3.2	3.9	4.4	4.7	4.7	4.6
COPR	-391	-7	49	56	52	45	38	31	25	20
COPH	-291	92	149	156	152	145	138	131	125	120

TH = 40.0 C DT = 36.0 C

I	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
V	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2
P	0.4	1.3	2.5	4.1	6.2	8.6	11.4	14.7	18.3	22.4
QH(O)	- 1.6	0.7	3.2	5.9	8.8	11.9	15.2	18.7	22.5	26.4
QC(I)	- 2.0	-0.6	0.7	1.8	2.7	3.3	3.8	4.1	4.1	4.0
COPR	-470	-44	26	63	42	38	33	27	22	17
COPH	-370	55	123	163	142	138	133	127	122	117

TH = 40.0 C DT = 40.0 C

I	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
V	0.5	0.7	0.9	1.0	1.2	1.4	1.6	1.8	2.0	2.2
P	0.5	1.3	2.6	4.2	6.2	8.7	11.5	14.8	18.4	22.4
QH(O)	- 2.0	0.3	2.8	5.5	8.4	11.4	14.7	18.2	21.9	25.8
QC(I)	- 2.5	- 1.0	0.2	1.3	2.1	2.8	3.2	3.5	3.5	3.4
COPR	-541	-77	8	30	33	31	27	23	19	15
COPH	-441	22	108	130	133	131	127	123	119	115

TH = 40.0 C DT = 44.0 C

I	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
V	0.5	0.7	0.9	1.1	1.3	1.5	1.7	1.9	2.0	2.2
P	0.5	1.3	2.6	4.3	6.3	8.8	11.6	14.8	18.4	22.5
QH(O)	- 2.4	-0.1	2.3	5.0	7.9	11.0	14.2	17.7	21.4	25.2
QC(I)	- 2.9	- 1.5	-0.3	0.8	1.6	2.2	2.6	2.9	2.9	2.7
COPR	-606	-109	-9	17	25	25	22	19	15	12
COPH	-506	-9	90	117	125	125	122	119	115	112

TH = 40.0 C DT = 48.0 C

I	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
V	0.5	0.7	0.9	1.1	1.3	1.5	1.7	1.9	2.1	2.2
P	0.5	1.4	2.7	4.3	6.4	8.8	11.7	14.9	18.5	22.5
QH(O)	- 2.8	-0.5	1.9	4.6	7.4	10.5	13.7	17.2	20.8	24.6
QC(I)	- 3.3	- 1.9	-0.7	0.2	1.0	1.7	2.1	2.3	2.3	2.1
COPR	-665	-139	-27	5	16	18	17	15	12	9
COPH	-565	-39	72	105	115	118	117	115	112	109

LOW RANGE PRESSURE TRANSDUCER
MODEL 237 Range: 0.2 to 5 psid and psia

DESCRIPTION
The Model 237 combines a rugged pressure sensor element and a unique new electroninc circuit* in a small flush-mounting transducer, enabling accurate low pressure measurement of liquids or gases. Unregulated 20 volt d.c. excitation; 5 volt d.c. output.

APPLICATIONS
The high level output signal, stability and accuracy over a wide range of operating temperatures, combined with fast dynamic response and inherent "squeeze-film" air damping make this instrument suitable for many industrial, laboratory and aerospace pressure measurements. Typical test applications include gas pressures, air speed and draft measurement, fluid dynamics, fluidics, biophysics, and model studies of pressure media compatible with 300 series stainless steel.

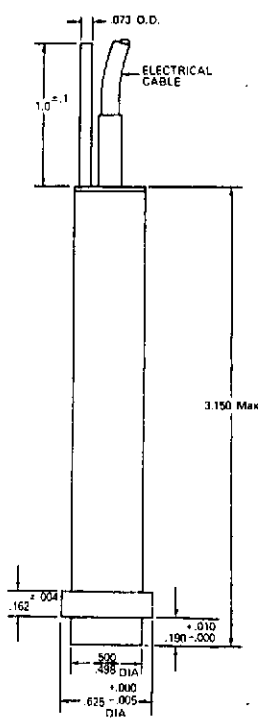
This group of transducers is used in flight test aircraft and wind tunnel models for dynamic pressure measurement. The Model 237 configuration is compatible with most pressure scanning systems.

CAPACITANCE TYPE SENSOR
A thin stretched stainless steel diaphragm, welded to the stainless steel case, forms a variable capacitance with an insulated electrode located very close to the diaphragm. The structure is simple, rugged and virtually hysteresis-free.

SELF-CONTAINED ELECTRONICS
The built-in electronics assembly is a unique variable pulse width modulation system* at a center frequency of approximately 100 KHz. Utilizing a specially developed switching-type integrated circuit, it converts the changes of the capacitance due to the pressure variations into a high level d.c. output signal. The high level, low impedance d.c. output is convenient to use, minimizes noise introduction and cable matching problems common to other types of transducers.

*U.S. Patent 3518536

FEATURES
- Flush-mounting configuration
- Differential or true absolute pressure.
- High level d.c. output; d.c. excitation.
- Internal voltage regulation.
- Low full scale pressure range (0.1 psi).
- High overload capability (as high as 100 psi).
- Low displacement volume: 10^{-5} cu. in.
- High natural frequency (5000Hz).
- Low gravitational and vibration effect.



Setra systems INC.
12 HURON DRIVE
NATICK, MASS. 01760
Telephone (617) 655-4645

MODEL 237 LOW RANGE PRESSURE TRANSDUCER

ADVANCE ENGINEERING RELEASE

SPECIFICATIONS

Ranges	
Unidirectional Differential	0-0.2, 0.5, 1, 5, 10 psid
Bidirectional Differential	0- ±.1, ±.25, ±.5, ±2.5, ± 5 psid
Absolute	0-0.2, 0.5, 1, 5, psia
Maximum Overload	100 psi, positive direction; 5x range in negative direction.
Pressure Media	Gases or liquids compatible with 300 series stainless steel.
Reference Media	Clean dry gas only, 30 psig maximum pressure.
Excitation*	15 to 30 volts d.c., 25 ma, for 0- ± 2.5V output; 20 to 30 volts d.c., for 0-5 V output.
Full Range Output**	
Unidirectional Differential	0-5 volt nominal
Bidirectional Differential	0- ± 2.5 volt nominal
Absolute	0-5 volt nominal
Output Impedance	< 20 ohms
Zero Output	< ± 100 mv at 77° F.
Non-Linearity	< ± .25% of full range output, (best straight line method).
Hysteresis***	< ± .1% of full range output, (infinite resolution)
Ambient Operating Temperature Limits	0° F to 175°F
Compensated Temperature Range	30° F to 150° F.
Thermal Zero Shift	< ± .015% full range/°F; 30° F to 150° F
Thermal Coefficient of Sensitivity	< ± .01% full range/°F; 30° F to 150° F
Acceleration Response	< 0.0002 psi/g typical.
Volume increase due to F.R. Pressure	1 x 10^{-5} cubic inches.
Natural Frequency	5000 Hz nominal.
Output Noise	< 5 mv RMS.
Weight	Approximately 1 oz.
Electrical Connections	Two feet of shielded cable (shield grounded to case).
Accessories Available	Flange mounting ring, pressure adapter, and "O" Ring seal.

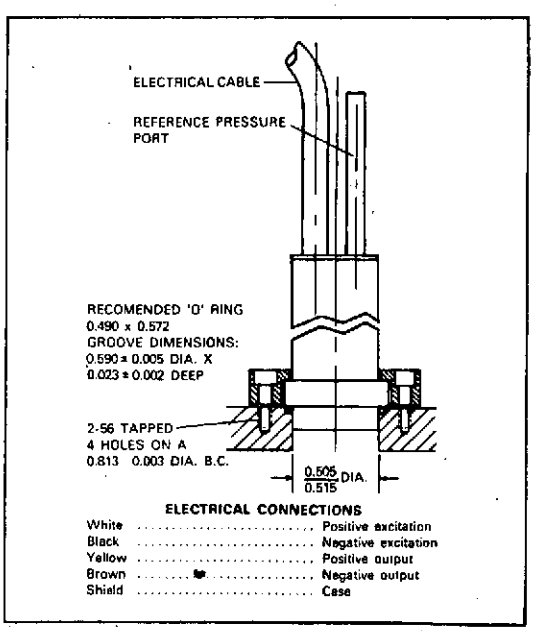
*Will not be damaged by excitation up to 30 volts d.c., or reversed excitation current.
NOTE: Observe excitation polarity prior to use.

**Calibrated into a 50K ohm load; operable into load impedances of 1K ohm or greater.
***Hysteresis slightly higher for 0-10 psid, ± 5 psid, and 5 psia units. (< ± .25% full range output)

INSTALLATION NOTES

The Model 237 pressure transducer is used in much the same way as a strain gage transducer. Both types of transducers are four terminal networks which can be grounded at only one point, either at an input or an output terminal, but not at both points. Power supply requirements also are identical. A single supply can be used to excite several transducers in parallel, but the transducer output terminal pairs cannot have a common connection.

The high output voltage and low output impedance enable direct read-out on voltmeters, oscilloscopes and recorder, or the powering of control loops or relays.



Prices and specifications subject to change without notice.
For modifications or special pressure ranges consult factory.

Setra systems INC.

Setra systems INC.

TRANSDUCER CALIBRATION CERTIFICATE

MODEL: 237 SER. NO.: 2176

PRESSURE RANGE: 0 - .2 PSID

EXCITATION: 24.00 VOLTS D.C.

ZERO PRESSURE OUTPUT*: - 49 mv

FULL RANGE SENSITIVITY*: 5.069 VOLTS

OUTPUT NOISE: .1 mv RMS

DATE OF INSPECTION: 4/2/73

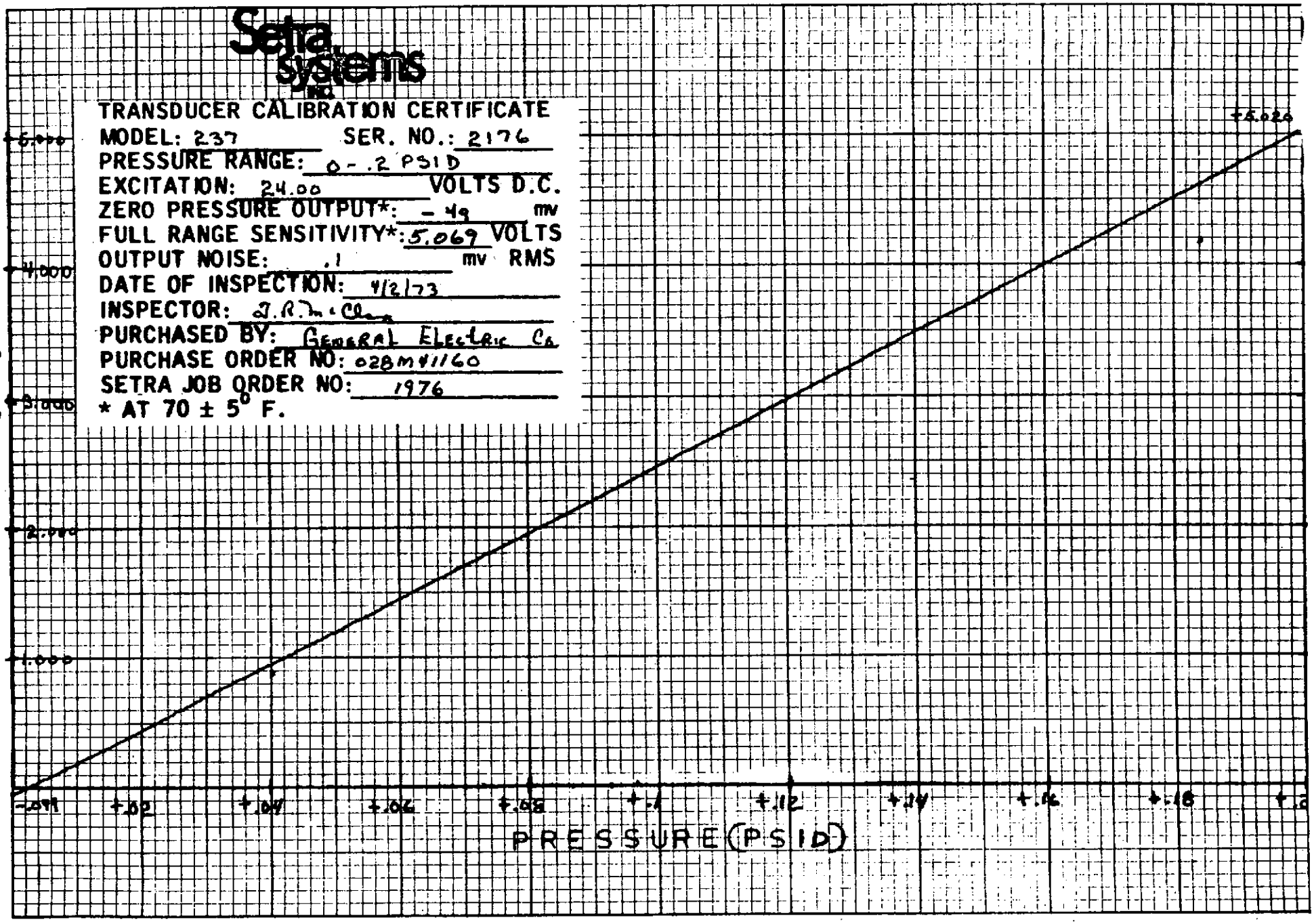
INSPECTOR: J. R. McClain

PURCHASED BY: General Electric Co.

PURCHASE ORDER NO: 028M411160

SETRA JOB ORDER NO: 1976

* AT 70 ± 5° F.



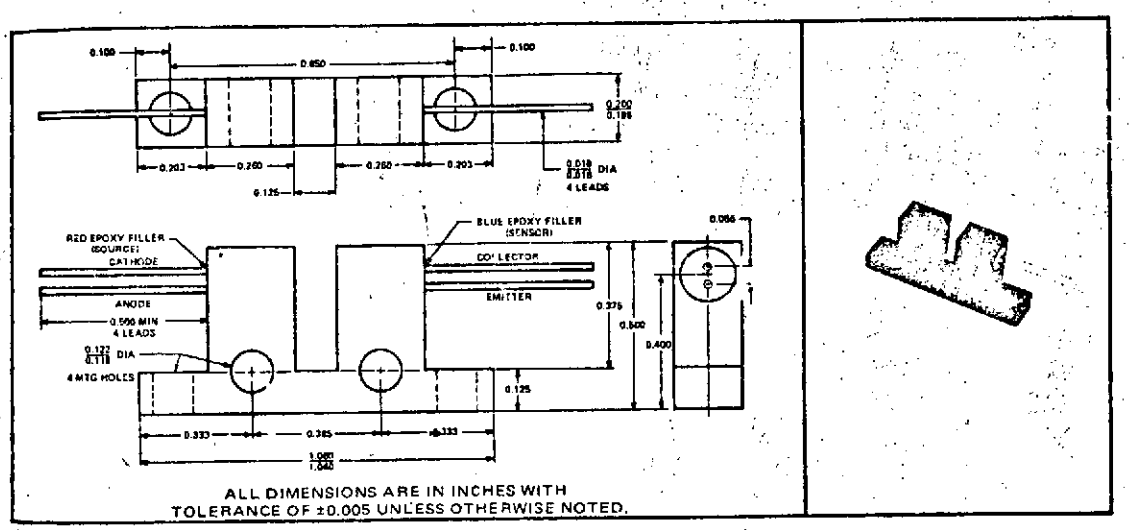
TYPE TIL138
BULLETIN NO. DL-S 7111558, SEPTEMBER 1971

OPTOELECTRONIC MODULE FOR TRANSMISSIVE SENSING APPLICATIONS

- Compatible With Standard DTL and TTL Integrated Circuits
- High-Speed Switching: t_r = 1.5 μs, t_f = 15 μs Typical
- Designed for Base or Side Mounting
- For Sensing Applications such as Shaft Encoders, Sector Sensors, Level Indicators, and Beginning-of-Tape/End-of-Tape Indicators

mechanical data

The assembly consists of a TIL32 gallium arsenide light-emitting diode and a TIL78 n-p-n silicon phototransistor mounted in a molded ABS† plastic housing. The assembly will withstand soldering temperature with no deformation and device performance characteristics remain stable when operated in high-humidity conditions. Total assembly weight is approximately 1.5 grams.



ALL DIMENSIONS ARE IN INCHES WITH TOLERANCE OF ±0.005 UNLESS OTHERWISE NOTED.

absolute maximum ratings at 25°C free-air temperature (unless otherwise noted)

Source Reverse Voltage	2 V
Source Continuous Forward Current (See Note 1)	40 mA
Sensor Collector-Emitter Voltage	50 V
Sensor Emitter-Collector Voltage	7 V
Sensor Continuous Device Dissipation at (or below) 25°C Free-Air Temperature (See Note 2)	50 mW
Storage Temperature Range	−40°C to 100°C
Lead Temperature 1/16 Inch from Assembly for 5 Seconds	240°C

NOTES: 1. Derate linearly to 80°C free-air temperature at the rate of 0.73 mA/°C.
2. Derate linearly to 80°C free-air temperature at the rate of 0.91 mW/°C.

†ABS thermoplastics are derived from acrylonitrile, butadiene and styrene.

electri naracteristics at 25°C free-air temperature

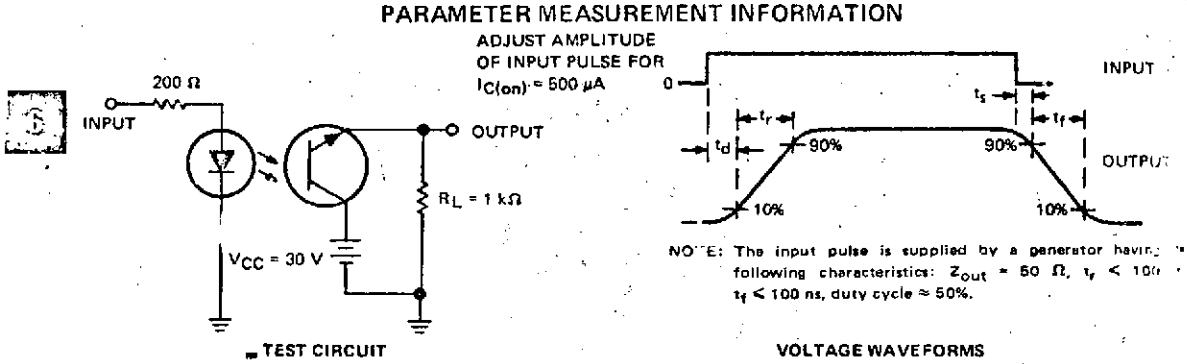
PARAMETER		TEST CONDITIONS†	MIN	TYP	MAX	UNIT
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	I_C = 100 μA, I_F = 0	50			V
$V_{(BR)ECO}$	Emitter-Collector Breakdown Voltage	I_E = 100 μA, I_F = 0	7			V
$I_{C(off)}$	Off-State Collector Current	V_{CE} = 30 V, I_F = 0			25	nA
$I_{C(on)}$	On-State Collector Current	V_{CE} = 0.5 V, I_F = 15 mA	0.4	1		mA
		V_{CE} = 0.5 V, I_F = 35 mA	1.6	4		
V_F	Input-Diode Static Forward Voltage	I_F = 15 mA		1.15	1.5	V
		I_F = 35 mA		1.2		

switching characteristics at 25°C free-air temperature

PARAMETER		TEST CONDITIONS†	MIN	TYP	MAX	UNIT
t_d	Delay Time	V_{CC} = 30 V, $I_{C(on)}$ = 500 μA, R_L = 1 kΩ, See Figure 1		3		μs
t_r	Rise Time			1.5		μs
t_s	Storage Time			0.5		μs
t_f	Fall Time			15		μs

†Stray irradiation outside the range of device sensitivity may be present. A satisfactory condition has been achieved when the parameter measured approaches a value which cannot be altered by further irradiation shielding.

PARAMETER MEASUREMENT INFORMATION



NOTE: The input pulse is supplied by a generator having the following characteristics: Z_{out} = 50 Ω, t_r < 100 ns, t_f < 100 ns, duty cycle ≈ 50%.

FIGURE 1–SWITCHING TIMES

TYPICAL CHARACTERISTICS

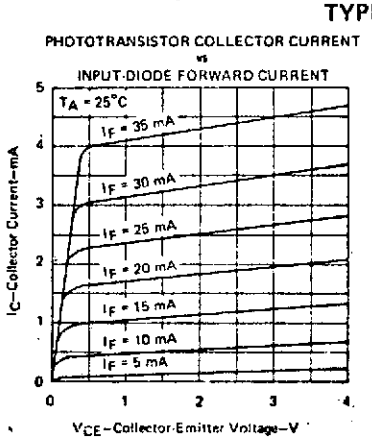


FIGURE 2

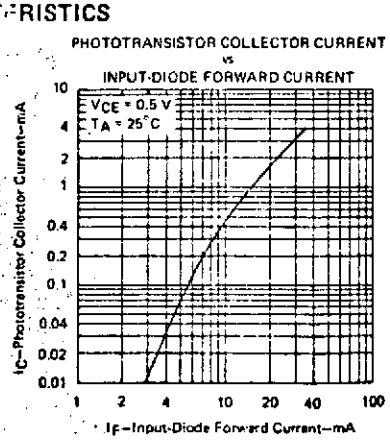


FIGURE 3

GENERAL ELECTRIC
SPACE DIVISION
PHILADELPHIA

PROGRAM INFORMATION REQUEST / RELEASE

PIR NO.	*CLASS. LTR.	OPERATION	PROGRAM	SEQUENCE NO.	REV. LTR.
	U	1R62	72	107	

*USE "C" FOR CLASSIFIED AND "U" FOR UNCLASSIFIED

FROM	TO
J. A. Geating, Biochemist Room #M-2112, VFSC	R. W. Murray, Program Manager-Life Systems Room #M-4618, VFSC

DATE SENT	DATE INFO. REQUIRED	PROJECT AND REQ. NO.	REFERENCE DIR. NO.
5-22-72			

SUBJECT

BIOLOGICAL REQUIREMENTS/RECOMMENDATIONS FOR THE AUTOMATED BIOWASTE SAMPLING SYSTEM

INFORMATION REQUESTED/RELEASED

1.0 Introduction

The measurements listed in Table 2.1 of The Statement of Work (SOW) have been reviewed with respect to the design requirements for an Automated Biowaste Sampling System (ABSS), i.e., urine, feces, vomitus. The probable assay, together with the sample volume/amount requirements, the possible chemical additives needed, and the storage/transport requirements were considered in the evaluation. The following represents the biological recommendations and constraints as they would apply to the design of the system.

In order to evaluate these requirements, it was necessary to define the basic assumptions upon which all biological conclusions ultimately rested. These assumptions are listed in the next section of this memo. The subsequent sections define the biological design constrains and recommendations respectively. In addition, a Summary Table is presented which contains in tabular form the information described in this memo.

2.0 Assumptions

The following assumptions were made as a basis for defining the biological requirements and choosing particular methods or changes when various alternatives existed. These assumptions involve basic ground rules provided in the SOW as well as additional ones considered necessary for the logical and rational completion of the mission.

- There will be a 6-man, all male crew.
- There will be a minimum re-supply time of 28 days.

cc: S. Gottlieb
M. Koesterer
J. Mangialardi

PAGE NO. 1 OF 12

RETENTION REQUIREMENTS

COPIES FOR	MASTERS FOR
1 MO.	3 MOS.
3 MOS.	6 MOS.
6 MOS.	12 MOS.
MOS.	MOS.
	DO NOT DESTROY

2.0 Assumptions (Continued)

- The primary purpose of the ABSS will be for the purpose of medical research, as contrasted to a mission limited only to medical monitoring.
- The list of measurements for which adequate samples are to be provided is based on Table 2.1 from the SOW. In the absence of a stated medical rationale, no additional measurements were considered except to suggest alternatives where assay methodology or preservation requirements dictated a possible need for change.

3.0 Biological Requirements/Design Constraints

3.1 Summary Table

Table 1, Appendix A, presents the measurement list together with the source of the biowaste for that measurement. Explanation or amplification of the remainder of the headings used in the Table are given below.

3.1.1 Analysis

Two major constraints exist for the choice between performing "On-Board or "Post-Flight" analyses:

- Need for real-time or semi real-time medical information for possible clinical monitoring, i.e., health and well-being of the crew, or
- Labile nature of the biowaste sample which tends to make post-flight analysis difficult.

The electrolytes, such as sodium, potassium, chloride, and calcium are intimately involved with the problem of water balance/loss. Thus, the monitoring of these ions on a consistant basis (daily) will probably be required. Also, the ratio of bound calcium to ionic calcium is of medical importance; preservation techniques which will permit subsequent analysis to reflect accurate representations of this ratio are not available.

3.1.2 Assay Requirements

Every effort was made to seek the latest assay techniques in currently accepted practice. These techniques, in turn, dictated the amount of sample required, either for preservation or for on-board or post-flight analysis. In some cases, recommendations/suggestions were made, either to delete the measurement or to transfer the measurement to a different sample. For example, it was recommended that the analysis for vasopressin, or anti-diuretic hormone (ADH), be performed on sera instead of on urine. In another instance, it was recommended that the protein determination on feces be eliminated.

3.1.3 Preservation/Storage Requirements

3.1.3.1 Additives Needed

The problems of pH control for urine or biological stabilizers for feces were considered and compatible recommendations made. These recommendations are discussed in more detail in the following section of this memo.

3.1.3.2 Temperature Required

Requirements were considered for storage temperatures which were compatible with not only the biological/assay requirements, but also with the power and space limitations imposed by engineering constraints.

3.2 Urine Sampling Requirements

3.2.1 Sample Collection

Freshly voided urine contains urea and other chemicals which break down very quickly causing alkaline pH, which in turn, causes heavy precipitation. The precipitation may result in the formations of complex structures that can make post-flight analysis for specific entities in representative quantities impossible. The alkaline pH may likewise cause denaturation of other substances with, similar consequences. Unpleasant and

undesirable odors also result from alkaline urine.

For these reasons, pH control will have to be maintained on all post-flight urine samples. Although some assays specify pH levels about 2 to 3, the design recommendation is suggested to be the maintenance of levels about 5.5 to 6.0. This may be achieved with various chemicals such as boric acid, hydrochloric acid, sodium metabisulfite, and various commercial buffered tablets which can be placed in the sample container. A further consideration is, of course, that the additive does not compromise the various assays for which the sample is intended. The satisfactory answer to this statement was considered outside the scope of this investigation.

Preservation of aerobic bacteria for post-flight identification will require an additive of different dimensions. In this case, the preservative must protect various bacterial species from loss of viability so that both identification as well as relative ratios of one species to another may be determined.

Requirements

- pH control 5.5 to 6.0.
- Additive
  - Bacterial Samples - TBD (Preliminary estimate is 50% veal influsion broth in 0.4% agar)
  - Chemical Assays - Sodium metabisulfite at concentration of 40% - amount/sample TBD
- Sampling - Two separate samples will be required, one for immediate on-board testing and the other for preservation for post-flight analysis. See Table 1.
- Volume
  - For on-board analysis, approximately 2 ml/sample without preservative is needed.
  - For post-flight analysis, at least 100 ml of a representative 24 hour pool will be required.

- Volume (Continued)

  - For bacterial analysis, 2 to 3 ml/sample as required and which contains no sodium metabisulfite.

3.2.2 Storage Temperature

The probability of isolating anaerobic bacteria from urine samples was considered remote. Therefore, storage temperatures which are employed by some investigators for preservation of anaerobes were not considered necessary. On the other hand, aerobic bacteria which may be present in certain urinary trait infections can be stored at refrigerator temperatures if the medium/preservative is adequate.

For post-flight chemical analyses, the storage of the samples at freezer temperatures is required. The combination of pH control and prompt storage at low temperature will provide acceptable protection for these samples.

Requirements

- Chemical analysis - temperatures in the range -70 to -100°C.
- Aerobic bacteria - refrigerator temperature of 3-5°C.

3.3 Feces Sampling Requirements

Sampling fecal waste for post-flight analysis involves two major considerations: Chemical Analysis and Microbiology. Each consideration is discussed separately in the sections below.

3.3.1 Chemical Analysis

The majority of the post-flight analyses can be accomplished on the dried residue from a known weight of the fecal sample. Since moisture content will be determined, it is recommended that enough sample, 30-40 gms, be subjected to the moisture determination so that the dried residue may be used for later analysis of electrolytes, various minerals, fatty acids, total nitrogen, and cellulose. The last item, cellulose, will require some

3.3.1 Chemical Analysis (Continued)

simple on-board manual preparations. This involves the staining of small quantities of the dry residue on a standard microscope slide and cover slip, and then storing at refrigerator temperatures. The slide may be examined immediately if the situation warrants on-board analysis, or may be saved for later determination.

3.3.2 Microbiology

Microbiological analysis involves two major subdivisions: anaerobic bacteria and aerobic bacteria.

3.3.2.1 Anaerobic Bacteria

Sampling and preservation of fecal waste for the quantitation and identification of anaerobic bacteria imposes severe stress on an Automated Biowaste Sampling System. The entire collection and sampling procedure must be accomplished in the complete absence of oxygen to prevent loss of viable species of anaerobes. Further, the satisfactory preservation of this sample for appropriate analysis as long as 30 to 35 days hence appeared to be an objective that could not be accomplished within reasonable limits, e.g., budgetary, scientific, or engineering.

A telephone communication with Dr. W. E. C. Moore, Director of the Anaerobic Laboratory at Virginia Polytechnic Institute produced the following information: Dr. Moore indicated that he has found no satisfactory method of preserving samples for anaerobic analysis for longer than 3-5 days. Even within this time, the species die-off rate approached 30-50% of the approximately 50 species that can be routinely isolated from human feces. He agreed that no subfreezing temperature could satisfactorily preserve anaerobes for periods of time up to 40 days.

The subject was also discussed with Dr. James McQueen of NASA-Houston Manned Space Center. He agreed that temperatures of -120°C, as indicated in the SOW, were not necessary for the chemical analyses scheduled for the biowaste samples. No definitive resolutions was reached concerning the preservation of samples for anaerobic analysis,

although he agreed with the conclusions of Dr. Moore mentioned above.

Since it has not yet been suggested that the fecal anaerobic bacterial population is a critical medical consideration, and since adequate methods for long term ($>$ 5 days) preservation do not exist, it is recommended that sampling and preservation for anaerobic analysis be deleted from the ABSS. One alternative to this would be to recommend on-board analysis. This was discussed with Dr. Moore; he indicated disagreement with this unless a) a highly qualified specialist in anaerobic identification (a difficult status to achieve) was included within the crew, and b) large quantities of time would be alloted during the flight for the analysis. Since neither event seems a likelyhood, the recommendation to delete this measurement was made.

3.3.2.2 Aerobic Bacteria

The aerobic bacteria, on the other hand, represent a study for which both on-board testing (contingency) and post-flight analyses must be made. Aerobic bacteria also tend to be quite labile when exposed to freezing and thawing procedures unless lyophylization, or freeze drying is employed. The use of freeze drying was rejected for the following reasons:

1.) Procedure would consume excessive crew time.

2.) Power and space requirements for the procedure would probably be unacceptable to engineering demands.

3.) The process does not lend itself well to automated procedures, especially with small numbers of samples.

Therefore, the method chosen was to thoroughly mix a 2-3 gm sample in a protective solution and preserve at 3-5°C. A tentative choice for this transport medium at present is a 50% veal infusion broth in a semi-solid gel such as 0.3 - 0.5% agar. Indications are that both quantitative as well as qualitative needs can be met with this procedure. A variation on this procedure involves growing out the initial samples using standard, on-board procedures, obtaining a relative count and then by the method above preserving isolated colonies carefully chosen from the original growth media.

Requirements

- Additives
  - Chemical Analysis: None; need dried residue from an accurately weighed 25-30 gm sample of freshly collected feces. Interface - Specimen Mass Measurement Devise(SMMD).
  - Bacterial Analysis: Mix with 2-3 gm (accurately weighed) sample of freshly collected feces.
- Weighing Accuracy: ± 100 mgm
- Temperature
  - Chemical Analysis: 3-5°C
  - Bacterial Analysis: 3-5°C

3.4 Vomitus Sampling Requirements

Since collection of vomitus is a random occurrence and the amount unpredictable, it is suggested that only pH control be exercised and the sample be frozen as rapidly as possible. The most effective method of collecting the vomitus will probably be in a strong, gas-impermeable plastic bag which contains a pre-measured quantity of a chemical for pH control. Bacterial analysis, if required, will probably be on-board, on a contingency basis.

Requirement

- Additive - For pH control: Sodium metabisulfite. Amount: TBD
- Temperature - At -70 to -100°C.

4.0 Recommendations

As suggested by Table 1, it was necessary to modify some of the measurements, delete others entirely, or re-assign them to different bio-samples as dictated by various constraints. These alterations/deletions are discussed individually in Section 4.1 immediately following.

Also, any project that attempts to encompass a task as broad as biowaste sampling must inevitably overlap some peripheral areas of biological science and engineering not defined

within the SOW. Additional discussion and concurrence with appropriate NASA personnel would be desirable to resolve some of the uncertainties arrising out of these overlapping areas. These uncertainties are discussed in Section 4.2.

4.1 Alterations/Deletion Recommendations

4.1.1. Urine

4.1.1.1 Hydrocortisone - Measurement was changed to an assay for urinocortisol which employs a minimum sample and more accurate test procedure.

4.1.1.2 Catecholamines - Measurement was altered to test for Metanephrin and Vanillylmandelic Acid (VMA) in place of Epinephrin and Norepinephrin respectively. They represent metabolites of Epinephrin and Norepinephrin, which are now regarded as more accurate reflections of the pressor/depressor level in the individual. The assay itself is considered more accurate and easier to accomplish.

4.1.1.3 Vasopressin or Antidiuretic Hormone (ADH) - This measurment was recommended to be deleted from the urine post-flight tests. Current information suggests that more accurate and meaningful data on the level of ADH in specific and the activity of the posterior pituitary gland in general can be gained from a serum assay rather than urine. Concentrations are higher and sample size required is significantly reduced.

4.1.1.4 Angiotensin and Renin - Recommend measurement be deleted from urine and added to a corresponding serum/plasma sample. This reflects higher concentration levels which can mean significantly earlier information on the ratio of these two hormones and possible indications of cardiac problems (hypertension).

4.1.1.5 Anaerobic Bacteria - This has been discussed in the previous Section (3.3.2.1). The recommendation is to delete the measurement from those which are to be implemented in the ABSS.

4.1.2 Feces

4.1.2.1 Moisture Content - This measurement was added to the list to provide needed information to total weight of fecal mass. The technique is serindipitus in that the by-product (dried solids) can be easily saved and stored for later use as samples for many of the scheduled fecal assays (See Table 1).

*This recommendation if accepted will impact the program in that automation is more difficult.

4.1.2.2 Protein - Recommended that measurement be deleted. This was discussed in some detail in previous Section 3.

4.1.2.3 Anerobic Bacteria - Recommendation to delete measurement. This was discussed in some detail in Section 3.

4.1.3 Vomitus

4.1.3.1 Aerobic Bacteria - Recommend deletion of measurement. The unpredictable nature and amount of the sample, plus the unsavory odor makes any extensive on-board manipulation of the sample-mass unacceptable. It is considered likely that chemical analysis of the contents would be of greater value. Therefore, it is recommended that adequate pH control be exercised via pre-added powder/tablets in the vomitus bags. The sample-mass must be weighed as rapidly as possible in the closed bag and frozen for post-flight analysis.

4.1.3.2 Anaerobic Bacteria - This measurement was also recommended to be deleted for reasons discussed above. Also, due to the nature of the collection, etc. it appears unlikely that anaerobic bacteria can be isolated from vomitus. Chemical analysis for a suspected bacterial endotoxin can be carried out on the frozen sample post-flight if symptoms warrant.

4.2 Discussion Areas

4.2.1 Consideration of Other Bio-samples

It appears likely that research on the effects of space flight on bio-wastes such as urine, feces, and vomitus in particular might be complimented by similar assays on other bio-samples such as serum/plasma and sweat. Many of the biological events of interest must be considered through analysis of all bio-samples. For example, electrolyte shifts and water balance cannot be adequately studied by assay of the urine and feces alone, but must include the results on serum and sweat as well.

4.2.1.1 Serum - As suggested by previous discussion in other sections, some assays originally assigned to urine can be carried out more accurately and conveniently on concurrent samples of serum or plasma, e.g. angiotensin and renin. Also, provision should be made for sufficient freezer space to accomodate these additional samples. The technique for preparing them for storage, such as centrifugation, addition or not of additives, etc., should be studied with a view towards complimentary activity with the other bio-samples.

4.2.1.2 Sweat - Since significant amounts of fluid loss in the body occurs through water vapor and sweat, it will be necessary to determine, as accurately and conveniently as possible, the quantitative and qualitative aspects of these losses. Assay of wash water for electrolytes can quantitate the mineral loss, but cannot give accurate estimates of the water loss associated with those electrolytes. Possible methods to accomplish these measurements and provision for their storage and return should be discussed before hardware construction is finalized.

4.2.2 Sample Preservation

Despite great volumes of literature associated with preservation of various bio-samples, questions and uncertainties remain. Can one or two simple preservation techniques satisfactorily preserve and transport all these samples, over a minimum of a 35 to

40 day period, for a wide variety of sensitive measurements? Some of these questions remain to be answered. A carefully constructed investigation which would serve not only the present measurement list, but also the anticipated needs of the future would be most desirable.

4.2.3 Effect of Additives on Post-Flight Assays

Associated with the foregoing topic is the question of the effect of the additives on the post-flight assay performed. Preservation studies may uncover the fact that pH adjustment was not low enough, or that an antibiotic must be present at the time of collection to prevent undesirable microbial activity. These questions need to be studied from a broad point of view to provide flexibility where required, and a firm base of information for future hardware design needs.

4.2.4 Separation of Collection System and Sampling System

It is suggested that the line between how a bio-sample is collected and how the sampling takes place is not always a firm one. In many cases, the two procedures/-requirements are inexorably tied together. An examination of the definitions of where one responsibility ends and the other begins should be undertaken.

5.0 Summary

Table 2, Appendix A, summarizes the essential recommendations and information concerning the Automated Biowaste Sampling System. Summaries of the total volume/weight of each Bio-waste Sample are shown below.

- Urine

  24 hour pool = 100 ml
  Individual Samples = 8.10 ml/micturition

- Feces

  Fresh Sample = 40 gm

- Vomitus

  As collected

Appendix A

TABLE 1

SAMPLING REQUIREMENTS FOR AUTOMATED WASTE SAMPLING SYSTEM

SOURCE	MEASUREMENT	ANALYSIS		ASSAY REQUIREMENTS		PRESERVATION/STORAGE REQUIREMENTS		COMMENTS/REMARKS
		ON-BOARD	POST-FLIGHT	DESCRIPTION/PROCESS	AMT. REQD.	ADDITIVES NEEDED	TEMP. REQD.	
Urine	Sodium (Na^+)	x		Ionic analysis using flow-thru specific ion electrodes	Approximately 2 ml Total	None-Should be assayed as soon as possible.	N/A	Sodium exists almost entirely in ionic form in Urine. Post-flight analysis by flame photometry also possible.
	Calcium (Ca^{++})	x		Ionic analysis using flow-thru specific ion electrodes		None-Should be assayed as soon as possible.	N/A	Calcuim may be complexed with other radicals in urine-therefore Post-flight analysis may not provide information needed.
	Potassium (K^+)	x		Ionic analysis using flow-thru specific ion electrodes		None-Should be assayed as soon as possible.	N/A	Concentration very important to maintenance of body water balance/ osmotic pressure.
	Chlorine (cl^-) (chlorides)	x		Ionic analysis using flow-thru specific ion electrodes		None-Should be assayed as soon as possible.	N/A	See remarks for Sodium.
	Magnesium		x	Total concentration by flame photometry	5 ml aliq. of 24 hour pool	pH control - i.e. ≤ 6.0	3 to 5°C	May be preserved at -100°C.
	Chromium		x	Total concentration by flame photometry	5 ml aliq. of 24 hour pool	pH control - i.e. ≤ 6.0	3 to 5°C	May be preserved at -100°C.
	Phosphates (as phosphorus P)		x	Spectrophotometric analysis	0.5 ml aliq. of 24 hour pool	pH control - i.e. ≤ 6.0	-70 to -100°C	Phosphates tend to break down rapidly, especially if sample becomes alkaline.
	Urea		x	Urea Nitrogen-precipitation with Xanthydrol	1 ml aliq. of 24 hour pool	pH control - i.e. ≤ 6.0	-70 to -100°C	
	pH	x		Electrochemical Technique-with flow thru electrode (in conjuntion with the	1 ml aliq.	None-Analysis should be performed as soon as possible.	N/A	pH can change rapidly due to enzymes and microbiological activity. Measurement must be made as soon as possible.

TABLE 1 (Continued)

SAMPLING REQUIREMENTS FOR AUTOMATED WASTE SAMPLING SYSTEM

SOURCE	MEASUREMENT	ANALYSIS		ASSAY REQUIREMENTS		PRESERVATION/STORAGE REQUIREMENTS		COMMENTS/REMARKS
		ON-BOARD	POST-FLIGHT	DESCRIPTION/PROCESS	AMT. REQD.	ADDITIVES NEEDED	TEMP. REQD.	
Urine (Cont)	ph (Continued)			electrolytes determined above) - Can also be determined directly with Dip Stick.				
	Blood Glucose Acetone Protein Bilirubin pH	x		Alternate Technique Can also be done directly with Dip Stick technique.	1 ml from each micturation	None-Analysis should be performed as soon as possible.	N/A	These are extra assays not requested from SOW, but capable of six discrete bits of real-time information.
	Amino Acid N		x	Spectrophotometric (for α amino acids only) using naphthoquinone	10 ml aliquot of 24 hour pool	pH control to < 6.0	-70 to -100°C	Quantitative analysis for individual amino acids will require significantly greater amounts of urine - need some clarification/-concurrence from NASA on selection.
	Proteins		x	Spectrophotometric - TCA	4 ml aliquot from 24 hour pool	pH control to < 6.0	-70 to -100°C	Several techniques exist to perform accurate quantitative protein assay. Alternate See under pH-Dip Stick technique can be employed for rough semi-quantitative protein determinations.
	Hydroxyproline		x	Amino Acid-chromatography, i.e., TLC, G.C.	15 ml aliquot of 24 hour pool	pH control to < 6.0 needed	-70 to -100°C	Specific Amino Acid-may be assayed as part of total AA separation by chromatographic technique-quantitation by densitometry.
	Aldosterone		x	Isotope/paper chromatography technique	15 ml aliquot of 24 hour pool	pH control to < 6.0 needed	-70 to -100°C	Exact amount of urine required for analysis determined by concentration appearing in sample.
	17-Hydroxy - corticosteroids		x	Purification & spectrophotometric assay	15 ml aliquot of 24 hour pool	pH control to < 6.0 needed	-70 to -100°C	See Above

SOURCE	MEASUREMENT	ANALYSIS		ASSAY REQUIREMENTS		PRESERVATION/STORAGE REQUIREMENTS		COMMENTS/REMARKS
		ON-BOARD	POST-FLIGHT	DESCRIPTION/PROCESS	AMT. REQD.	ADDITIVES NEEDED	TEMP. REQD.	
Urine (Cont)	Hydrocortisone		x	Isotopic method but test for urinocortisol	5 ml aliquot of 24 hour pool	pH control to <6.0	-70 to 100°C	Newer techniques allow for accurate analysis in urine.
	Catecholamines							
	Epinephephrine		x	Recommend change to metanephrin and VMA det'n. by TLC	5 ml aliquot from 24 hour pool	pH control to < 6.0 needed	-70 to -100°C	Sample must be frozen as quickly as possible to prevent enzyme degradation or organic breakdown. Accuracy and sensitivity of metanephrin and VMA assay increases value of determination.
	Norepinephephrine		x			pH control to <6.0	-70° to -100°C	
	Vasopressin (ADH)	N/A		Recommend delete from urine meas. and resubmit as serum measurement.				Sensitivity of serum technique surpasses urine measurement as technique of choice.
	Creatinine		x	Spectrophotometric	10 ml aliquot	pH control needed 3.0	-70 to -100°C	See Above. Confirmation of pH control to 3.0 - TBD
	Angiotensin	N/A		Recommend measurement be made on Serum/plasma samples from subjects.	N/A	N/A	N/A	These two substances difficult to assay in urine (low concentration) and therefore require excessive sample size which impacts sampler performance. Serum tech. more accurate, faster, easier.
	Renin							
	Microbiology 1. Aerobic	x		Specific test agar (Special Devices) Exact procedure/-medium dependent upon apparent infection and symptomatology.	2 ml each sample	None (On-Board Technique)	N/A	On-Board apparent infections will require immediate analysis to determine treatment regimen and provide qualitative/quantitive values.
			x	Mix with special medium containing veal infusion broth with agar.	2 ml each sample	Media provides control of pH and isotonicity.	3 to 5°C	Exact regimen for preserving samples for bacteria analysis requires R&D.
	2. Anaerobic	N/A	N/A	Unlikely source of anaerobic bacteria Recommend deletion	N/A	N/A	N/A	———

TABLE 1 (Continued)

SAMPLING REQUIREMENTS FOR AUTOMATED WASTE SAMPLING SYSTEM

SOURCE	MEASUREMENT	ANALYSIS		ASSAY REQUIREMENTS		PRESERVATION/STORAGE REQUIREMENTS		COMMENTS/REMARKS
		ON-BOARD	POST-FLIGHT	DESCRIPTION/PROCESS	AMT. REQD.	ADDITIVES NEEDED	TEMP. REQD.	
Feces	Moisture Content	x		Gravimetric determination with drying of sample - I/F with SMMD. Residue must contain ≥ 5 gm dried material.	30 gm.	N/A (on-board technique)	N/A	Dried residue will be saved to perform post-flight determinations on the Electrolyte concentration, etc.
	Potassium Sodium Calcium Chloride Phosphorus Chromium Magnesium		x	All determinations carried out by appropriate methods, e.g., flame photometry, wet chemistry, gravimetric, etc.	2-3 gm. dried residue	None	3-5°C	Container must be vapor tight to prevent re-hydration of dried residue (derived from moisture determines above).
	Nitrogen		x	Micro-Kjeldahl for Total N	1.5 gm. of dried residue	None	3-5°C	See Above
	Fatty Acids		x	Gravimetric Technique	0.5 gm. of dried residue	None	3-5°C	See Above
	Carbohydrates		x	Determination of Reducing Substances	3 gm. fresh sample of feces	None	-70 to -100°C	Specimen must be frozen as soon as possible.
	Cellulose	x	x	Stained Microscopic prep. employing 3 separate stain procedures-Save for post-flight confirmation	0.5 gm. fresh sample	None	3-5°C	Slides must be kept tightly wrapped to prevent evaporation of moisture.

TABLE 1 (Continued)

SAMPLING REQUIREMENTS FOR AUTOMATED WASTE SAMPLING SYSTEM

SOURCE	MEASUREMENT	ANALYSIS		ASSAY REQUIREMENTS		PRESERVATION/STORAGE REQUIREMENTS		COMMENTS/REMARKS
		ON-BOARD	POST-FLIGHT	DESCRIPTION/PROCESS	AMT. REQD.	ADDITIVES NEEDED	TEMP. REQD.	
Feces (Cont)	Protein	N/A		Recommend eliminate from Measurement	N/A	N/A	N/A	Information Value doubtful (See Note - PIR) due to uncertain nature of original percentage composition.
	Microbiology 1. Aerobic	x		• As dictated by needs of the moment, i.e, standard bacteria technique & methods, etc.	N/A	N/A (on-board technique)	N/A	Real-Time experimental research type operation or contingency assay for medical purposes.
			x	• Standard bacteria technique for identification of microorganisms and quantification	4-5 gm. fresh specimen	Dependent upon priority and Preservation/Storage capabilities 1. Incorporate in 1 or more special medium, e.g., veal broth with 0.4% agar "Transport Media" - TBD. 2. Plate out original sample & obtain quantitive count, then preserve pure cultures of individual colonies for post-flight I/D.	3-5°C	This requirement as per conversation with Dr. J. McQueen-Exact method still TBD based on R&D now in progress.
	2. Anaerobic	N/A		Recommend elimination of anaerobe samples from measurement list.	N/A	N/A	N/A	As per conversation with Dr. W.E. C. Moore, Virginia Polytec. Inst. No reliable technique for preserving anaerobes for more than 3-4 days - beyond that, species die-off is too high to be acceptable for good isolation work.

TABLE 1 (Continued)

SAMPLING REQUIREMENTS FOR AUTOMATED WASTE SAMPLING SYSTEM

SOURCE	MEASUREMENT	ANALYSIS		ASSAY REQUIREMENTS		PRESERVATION/STORAGE REQUIREMENTS		COMMENTS/REMARKS
		ON-BOARD	POST-FLIGHT	DESCRIPTION/PROCESS	AMT. REQD.	ADDITIVES NEEDED	TEMP. REQD.	
Vomitus	Sodium Potassium Calcium Chlorides Phosphorus Magnesium Chromium		x	Appropriate techniques to quantitate amounts.	Entire Sample	pH control to < 6.0	-70 to -100°C	Entire sample must be collected, weighed accurately ($\pm$ 1 gm), and preserved at freezer temperature for post-flight analysis. Since sample size impossible to predict, adequate provision possible.
	Proteins Carbohydrates Cellulose Fatty Acids		x	Appropriate techniques as mediated by volume of sample collected	Entire Sample	pH control to < 6.0	-70 to -100°C	As Above
	Microbiology							
	1. Aerobes	x		As dictated by on-board conditions.	N/A	N/A	N/A	——
			N/A	Homoginizing and apportioning difficult to these samples - Recommend deletion.	N/A	N/A	N/A	Medical usefullness doubtful.
	2. Anaerobes		N/A	Recommend deletion - Highly unlikely source.	N/A	N/A	N/A	Examine sample for endotoxin.

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G. L. Fogal, Program Manager - Environmental Engineering, Room #M-2101, VFSC X-5636	Distribution

DATE SENT	DATE INFO. REQUIRED	PROJECT AND REQ. NO.	REFERENCE DIR. NO.
10 Sept 1973		ABSS	

SUBJECT

DISINFECT SEQUENCE RINSE REQUIREMENTS

INFORMATION REQUESTED/RELEASED

PIR 1R62-73-103 examined disinfect sequence water rinse requirements assuming a 25 and 50 ml system residual for the Urine Subsystem. Based on comparison with the mofified USCS configuration, a more realistic estimate of system residual is 11 ml. Figure 1 shows that the iodine concentration after 4 100% effective water rinses is well under 10 ppm. If the system residual should vary to a value as high as 15 ml, the available iodine concentration after 4 water rinse cycles will only be 6.2 ppm, still below the 10 ppm desired to ensure no effect on subsequent urine chemical analyses.

Based on the above, the disinfect sequence cycle can be modified (See PIR 1R62-73-103)to provide 4 instead of the 5 rinse cycles.

h

cc: J. K. Mangialardi
G. L. Fogal (3)

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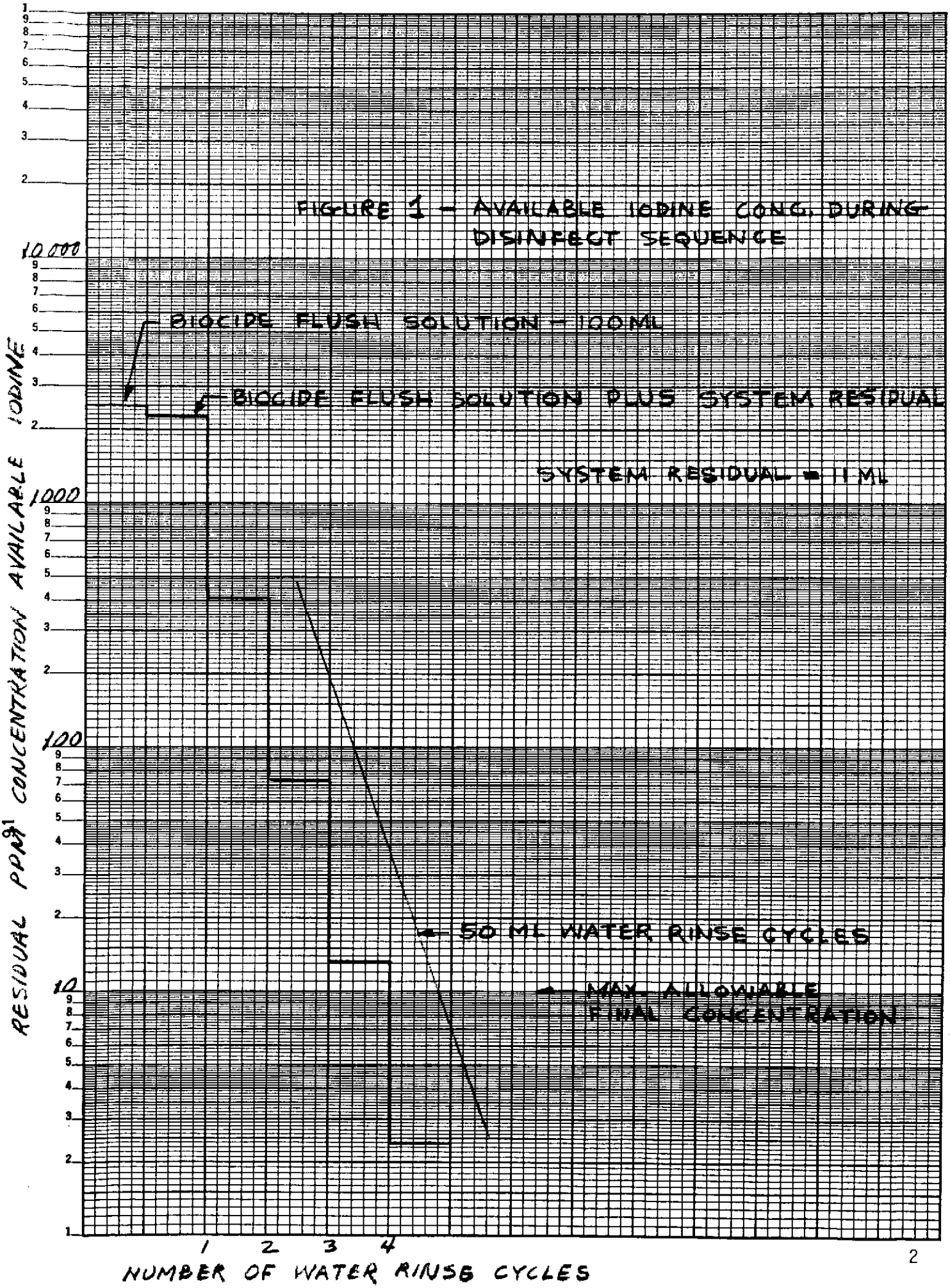
FIGURE 1 – AVAILABLE IODINE CONC. DURING DISINFECT SEQUENCE
BIOCIDE FLUSH SOLUTION – 100ML
BIOCIDE FLUSH SOLUTION PLUS SYSTEM RESIDUAL
SYSTEM RESIDUAL = 11 ML
50 ML WATER RINSE CYCLES
MAX. ALLOWABLE FINAL CONCENTRATION
RESIDUAL PPM AVAILABLE IODINE CONCENTRATION
NUMBER OF WATER RINSE CYCLES
10,000
1000
100
10
1
2
3
4

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DATE SENT	DATE INFO. REQUIRED	PROJECT AND REQ. NO.	REFERENCE DIR. NO.
1-23-73		ABSS	

SUBJECT

Biocide and Rinse Water Requirements

INFORMATION REQUESTED/RELEASED

As presently planned, at the end of each 24 hour period, the ABSS Urine Subsystem will be sterilized by use of a biocide flush followed by a water rinse. This sterilization sequence is shown in Figure 1. The biocide flush solution and water rinse volumes are based on the data shown in Table 1, Condition B; available iodine in the incoming biocide flush solution was assumed to be 2500 ppm. According to M. Koesterer, a 2500 ppm (± 20%) concentration of available iodine (from Betadine) should be satisfactory. He has also indicated that the available iodine in the system residual (at end of sterilization) must not exceed an estimated 10 ppm concentration in order to ensure no effect on subsequent urine chemical analyses. Figure 2 illustrates the available iodine concentration during each stage of the overall sterilization sequence.

cc: M. Koesterer
R. W. Murray
G. L. Fogal

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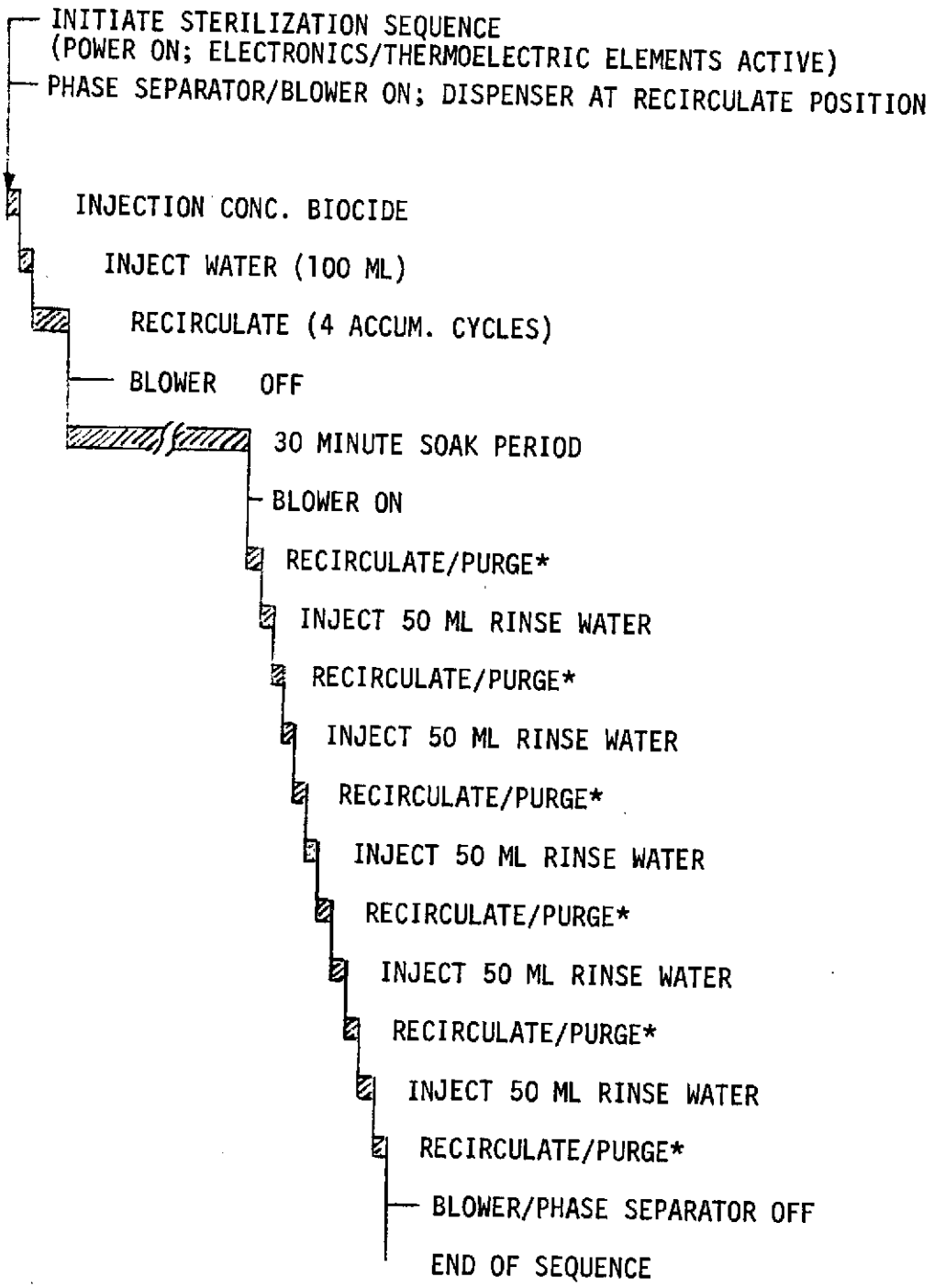
FIGURE 1 - ABSS URINE SUBSYSTEM STERILIZATION SEQUENCE (NOT TO SCALE)



*3 RECIRCULATE FOLLOWED BY 3 DUMP CYCLES OF ACCUMULATOR

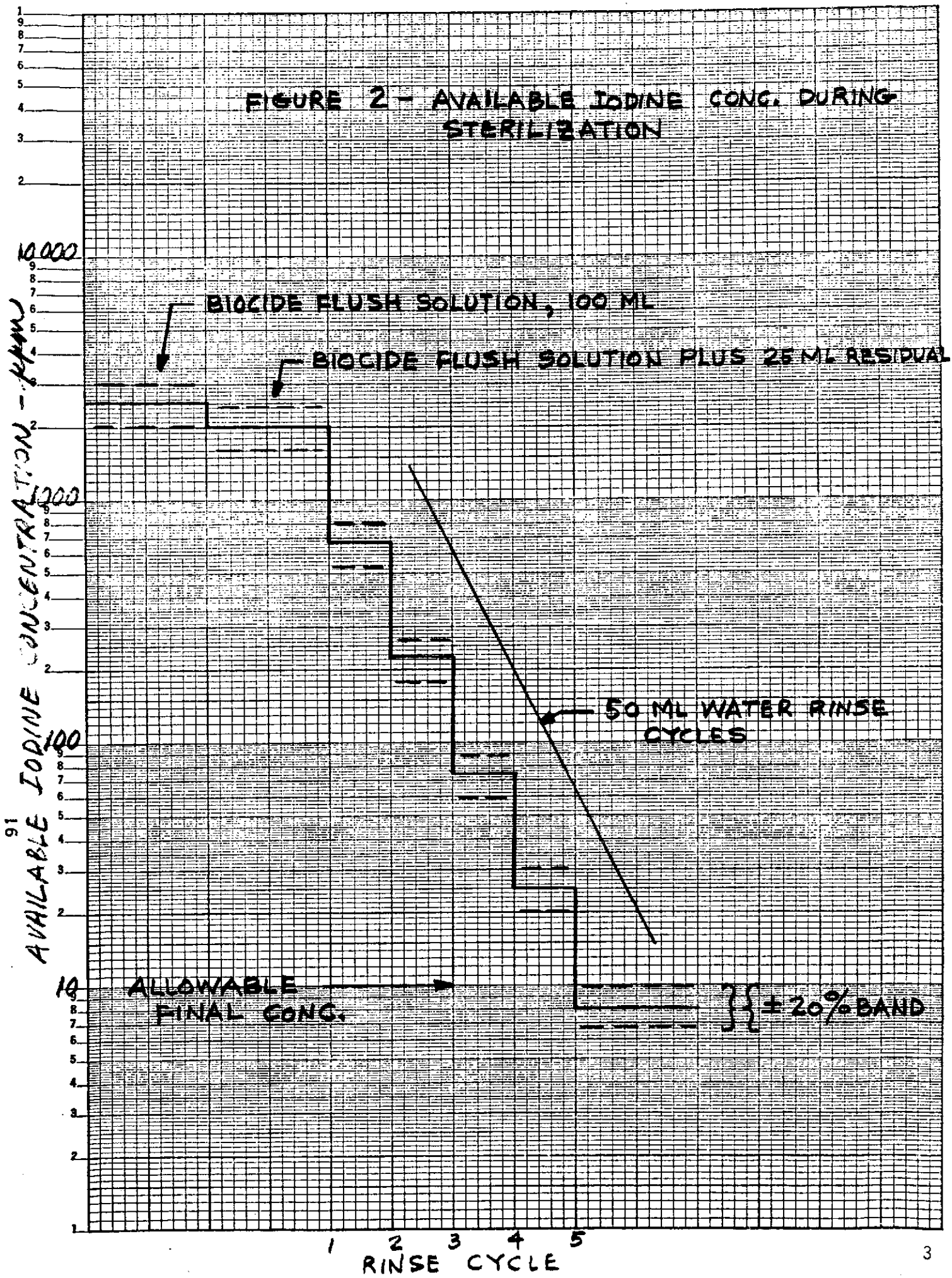


FIGURE 2 - AVAILABLE IODINE CONC. DURING STERILIZATION
BIOCIDE FLUSH SOLUTION, 100 ML
BIOCIDE FLUSH SOLUTION PLUS 25 ML RESIDUAL
50 ML WATER RINSE CYCLES
ALLOWABLE FINAL CONC.
± 20% BAND
AVAILABLE IODINE CONCENTRATION - PPM
10,000
1,000
100
10
1
1 2 3 4 5
RINSE CYCLE

TABLE 1 - RINSE WATER VOLUME REQUIREMENTS

	INDIVIDUAL WATER RINSE VOLUME	NUMBER OF RINSE CYCLES*	TOTAL RINSE VOLUME	FINAL IODINE ppm
Condition A:	25 ml system residual and 50 ml biocide flush (Iodine ppm = 2500)			
	25 ml	8	200 ml	6
	50	5	250	7
	75	4	300	7
	100	4	400	7
Condition B:	25 ml system residual and 100 ml biocide flush (Iodine ppm = 2500)			
	25 ml	8	200 ml	8
	50	5	250	8
	75	4	300	8
	100	4	400	3
Condition C:	50 ml system residual and 50 ml biocide flush (Iodine = 2500 ppm)			
	25 ml	12	300 ml	9
	50	7	350	10
	75	6	450	5
	100	5	500	5
Condition D:	25 ml system residual and 50 ml biocide flush (Iodine = 2500 ppm)			
	4170 ml	1	4170 ml	10

*After biocide flush and each rinse cycle, pump-out liquid

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FROM	TO
Martin G. Koesterer, Microbiologist Life Sciences M2112 - Ext. 5654	John Mangialardi ABSS Project M4618 - Ext. 5499

DATE SENT	DATE INFO. REQUIRED	PROJECT AND REQ. NO.	REFERENCE DIR. NO.
1/19/73	--	Automated Biowaste	--

SUBJECT

ABSS BIOCIDE SELECTION

INFORMATION ~~REQUESTED~~/RELEASED

Attached is a brief account regarding the selection and properties of a bactericide for use in the Automated Biowaste Sampling System.

R. Murray
F. DiSanto
G. Fogal
File

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Properties and Selection of a Bactericide for the Automated Biowaste Sampling System

Introduction

In order to preserve the integrity of biowaste samples for biomedical experimental purposes and to decontaminate the hardware of such a waste sampling system safely, several approaches have been proposed. They range from steam sterilization to mere rinses with sterile water to accomplish the task. These could be performed after each and every use, once a day or be combined i. e., water rinse after every use followed by once a day flushing with bactericide. This latter approach appears to be realistic. As part of various projects, NASA and NASA contractor scientists have made a continual search for a safe bactericide compatible with space hardware.

One bactericide which has been selected for use on the SKYLAB program and which, according to NASA personnel, is effective and compatible with materials expected to be used in the spacecraft and any of its subsystems, is betadine (povidone iodine).

The following summarizes the properties of the compound and the approximation of concentration which should satisfy the microbial control requirement. It would appear, pending either receipt of or development of reliable information to the contrary, that betadine would be useful in space applications. It can be considered for use in biomedical hardware because minimum residuals can be attained either by dilution with biological materials such as urine, or if required by following its application with a sterile distilled water rinse. Determination of the minimum concentration which might cause interference with subsequent biochemical analysis of biological sample materials.

Properties of Betadine

Betadine is a water soluble complex of iodine and polyvinylpyrrolidone (povidone) produced by the Purdue Frederick Company of New York City which possesses the well-known properties of iodine. The generally available betadine solution is an aqueous solution containing 10 percent povidone-iodine, with one percent available iodine. More concentrated solutions are available, containing up to 50%iodine. The manufacturer has had quite a bit of experience with a 30% concentration.

Betadine retains the unique, non-selective, universal microbicidal activity of iodine, yet is virtually non-irritating to skin or mucous membranes, and is non-staining to skin and naterual fabrics. It is compatible with various buffers for long periods of time. It is compatible with the higher grades of stainless steel (i. e., #314 and above) but causes some corrosion (oxidation) in lesser grades.

As regards effective concentrations, the Purdue Frederick literature cites applications of as low as 1:2000 dilutions of 10% betadine solution as being effective against a broad range of microorganisms for periods from 30 minutes up to several hours.

The following table presents the concentration of the 10% betadine solution versus the corresponding effective concentration of iodine:

Concentration of Betadine Solution		Corresponding Amount of Available Iodine
10%	30%	
Undiluted	1/3	1% or 10,000 ppm
1/4	1/12	0.25% or 2500 ppm
1/10	1/30	0.1% or 1000 ppm
1/100	1/300	0.01% or 100 ppm

Practical applications of iodine as an antimicrobial agent indicate that concentrations of from 0.5 to 2% of free iodine are effective in disinfecting surgical instruments and equipment. As a result of this data and discussion with other professional microbiologists, it is felt that a 1:4 diluted solution of the 10% betadine (0.25% available iodine) would satisfactorily control the microbial population in clean systems.

Regarding the volume of concentrated bactericide required for a system like ABSS, the following estimate can be made:

Assuming Flush w/Biocide Each Use	Assuming one Decontam. per Day
6 men	
7 flushes (urinations) per day	
28 day mission	28 day
50 ml flush	100 ml flush
Total flush vol $\tilde{=}$ 60 liters at .25% available iodine from 30% Betadine solution	2800 ml total flush
Need ~ 150 ml of available iodine or Betadine 5 liters of 30%	Need ~ 230 ml of 30% Betadine

For purposes of specifying concentration of betadine, the minimum concentration would be 0.25% $\pm$ 0.05%.

Estimation of Betadine Residual from Flushing

Since the only apparent problem with a chemical decontaminant appears to be possible interference by any residual with any biochemical analytical technique to be performed as part of the biomedical experiment, it is necessary to analyze the potential for that impact.

It has been determined that a few ppm (1-10) of iodine should not interfere with the usual tests envisioned. This remains to be confirmed, especially for the specific tests identified earlier in the ABSS project.

Based merely on calculation of the dilution during a normal operating cycle, seven rinses with a volume of urine or water, assuming uniform mixing and a homogenous suspension, the final concentrations in any sample would be as follows:

2500 ppm in original flush.
↓ rinse 1
1250 ⟶ in 1st sample
↓ rinse 2
625
↓ rinse 3
312
↓ rinse 4
156
↓ rinse 5
78
↓ rinse 6
39
↓ rinse 7
19 ⟶ in 7th sample

If larger rinse volumes of urine are processed, the concentrations would be much less.

If both urine and water were flushed thru the system, even lower residuals would be achieved.

Testing on Prototype Hardware

As part of the test phase on the prototype ABSS unit, several basic tests should be performed for the following basic determinations:

a. The actual residual viable microbial level in the system after clean assembly and after usage (single and multiple).

b. The efficacy of several dilutions (concentrations) of the bactericide in the actual hardware under use conditions.

c. The compatibility of the hardware to the biocide over a prolonged period.

These basic tests will involve respectively:

a. Assaying by means of a sterile water or buffer purged through the system.

b. Exposing test bacterial contaminants to the 0.25% betadine.

c. Submersing and allowing selected materials or components to the betadine for times longer than would be expected in practice.

Date: 31 January 1973

AUTOMATED BIOWASTE SAMPLING SYSTEM

URINE SUBSYSTEM OPERATING MODEL

DESIGN SPECIFICATION

1.0 SCOPE

This specification defines the performance and design requirements for the Urine Subsystem portion of the Automated Biowaste Sampling System Operating Model and establishes requirements for its design, development and test.

All contract end items of the Urine Subsystem shall conform to the requirements stated herein.

1.1 Purpose

The purpose of the Urine Subsystem Operating Model shall be to provide conceptual verification of an equipment assembly applicable to manned space flight and which automatically provides for the collection, volume sensing and sampling of urine from human subjects.

1.2 Definitions

For the purposes of this document, the following definitions and abbreviations shall apply:

Later

2.0 APPLICABLE DOCUMENTS

Statement of Work, as modified, Contract NAS 1-11443.

3.0 REQUIREMENTS

3.1 Performance

3.1.1 Functional Requirements

3.1.1.1 Primary Performance Requirements

3.1.1.1.1 Measurement Requirements

The Urine Subsystem Operating Model shall measure the total quantity of urine voided by a human subject. Each micturition (35 ml minimum) shall be measured within an accuracy of ± 1%.

3.1.1.1.2 Collection Requirements

The Urine Subsystem Operating Model shall collect the total quantity of urine voided by a human subject. Specifically, the Operating Model shall have the capability to handle the following urine input volumes and flow rates for a crew of six (6) men.

a. Average output of 2000 ml/man/24 hours
b. Maximum output of 4000 ml/man/24 hours
c. Minimum output of 600 ml/man/24 hours
d. Maximum output of 18,000 ml/6 men/24 hours
e. Minimum output of 5000 ml/6 men/24 hours
f. Maximum delivery rate shall be 45 ml/second
g. Maximum single micturition of 1000 ml
h. Minimum single void of 35 ml
i. Average of 7 micturitions/man/24 hours
j. Minimum of 5 micturitions/man/24 hours
k. Mamimum of 10 micturitions/man/24 hours
l. Minimum of 30 micturitions/6 men/24 hours
m. Maximum of 54 micturitions/6 men/24 hours

3.1.1.1.3 Sampling Requirements

The Urine Subsystem Operating Model shall provide representative individual micturition and 24-hour pool samples for each subject with specific requirements

as follows:

a. Microbiological Sample

The Operating Model shall provide individual user identified sample containers for collecting a nominal 2 ml sample of urine from each micturition.

b. Chemical Sample

The Operating Model shall provide individual user identified sample containers for collecting a nominal 5 ml sample from each urination.

c. 24-Hour Pool Sample

The Operating Model shall provide individual user identified sample containers for collecting a 110 ml representable 24-hour urine pool sample from each user.

Micturitions below 50 ml will not contribute to this sample. The 110 ml sample volume shall be obtained by directing nominal 10% of each urination (over 50 ml and separately by subject) into each sample container and at the end of the 24-hour period reducing the volume to 110 ml. The 24-hour pool sample container shall be located in a refrigerated space held at -5 to 10°C during collection of the sample.

Free gas present in the 24-hour pool samples shall be less than 0.1%.

d. Small Micturition Samples

The Operating Model shall collect small micturitions (less than 50 ml) in total.

3.1.1.1.4 Equipment Requirements

The Urine Subsystem Operating Model shall conform to the functional block diagram of Figure 3.1.1.1-1.

3.1.1.1.4.1 Displays

The Operating Model shall provide a visual indication of operational status.

3.1.1.1.4.2 Power Conditioning

The Operating Model shall be designed to operate on nominal 28 VDC power.

3.1.1.1.4.3 Gravity Field

The Operating Model shall be designed for gravity independent operation. However, performance will be demonstrated for normal earth gravity conditions only.

3.1.1.1.4.4 Configuration

The Operating Model shall be configured to provide both a functional and attractive appearance representative of a possible flight configuration. The Model need not be optimized for minimum size, weight or power input.

3.1.1.1.4.5 Operation

The Operating Model shall be designed for a high degree of automatic operation. Micturition preparation time shall not exceed 30 seconds.

3.1.1.1.4.6 Data Output

The Operating Model shall correlate micturition volume and time with the corresponding sample containers and user, and interface this information with an external recorder.

3.1.1.1.4.7 Maintenance

The Urine Subsystem Operating Model shall be designed to be easily maintainable including replacement of components.

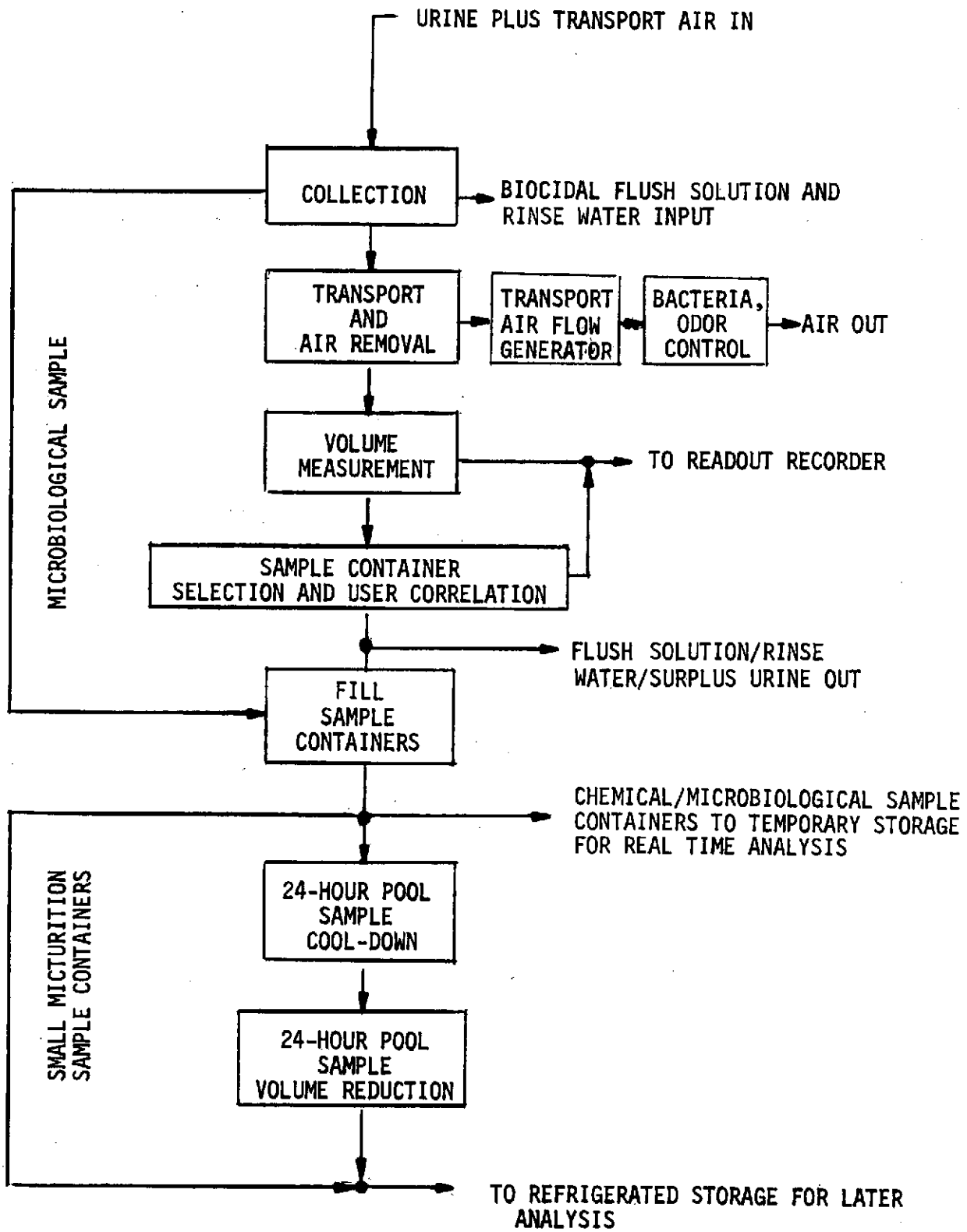


FIGURE 3.1.1.1-1 URINE SUBSYSTEM OPERATING MODEL FUNCTIONAL BLOCK DIAGRAM

3.1.1.1.4.8 Contamination

To prevent cross-contamination and possible sample degradation, the Operating Model shall be designed for an automatic water rinse after each micturition. On command of the operator, the Model shall provide a biocidal sterilization cycle.

3.1.1.2 Secondary Performance Requirements

The Urine Subsystem Operating Model shall conform to the block diagram of Figure 3.1.1.2-1 and operating sequences of Figure 3.1.1.2-2.

3.1.1.2.1 The Urine Subsystem Operating Model shall be configured to fit within an envelope of 24 inches high, 14 inches wide and 14 inches deep.

3.1.1.2.2 Weight

The Operating Model shall not be weight constrained.

3.1.1.2.3 Component Description

3.1.1.2.3.1 Urinal Assembly

The urinal assembly serves as the urine collection agency for the overall subsystem. Specific design requirements are as follows:

a. The urinal shall be an open funnel type design with a minimum entrance opening of approximately 4.0 square inches.
b. The urinal shall not use a honeycomb (or equal) insert.
c. The urinal shall be easily held by one hand.
d. The urinal shall be configured to minimize contamination.
e. The urinal shall be connected to the phase separator by a non-metallic flexible line (nominal 0.375 ID).
f. The urinal assembly shall physically accomodate and be compatible with the microbiological sample containers.
g. The urinal assembly shall be compatible with and accomodate both a biocidal solution flush and a water rinse.

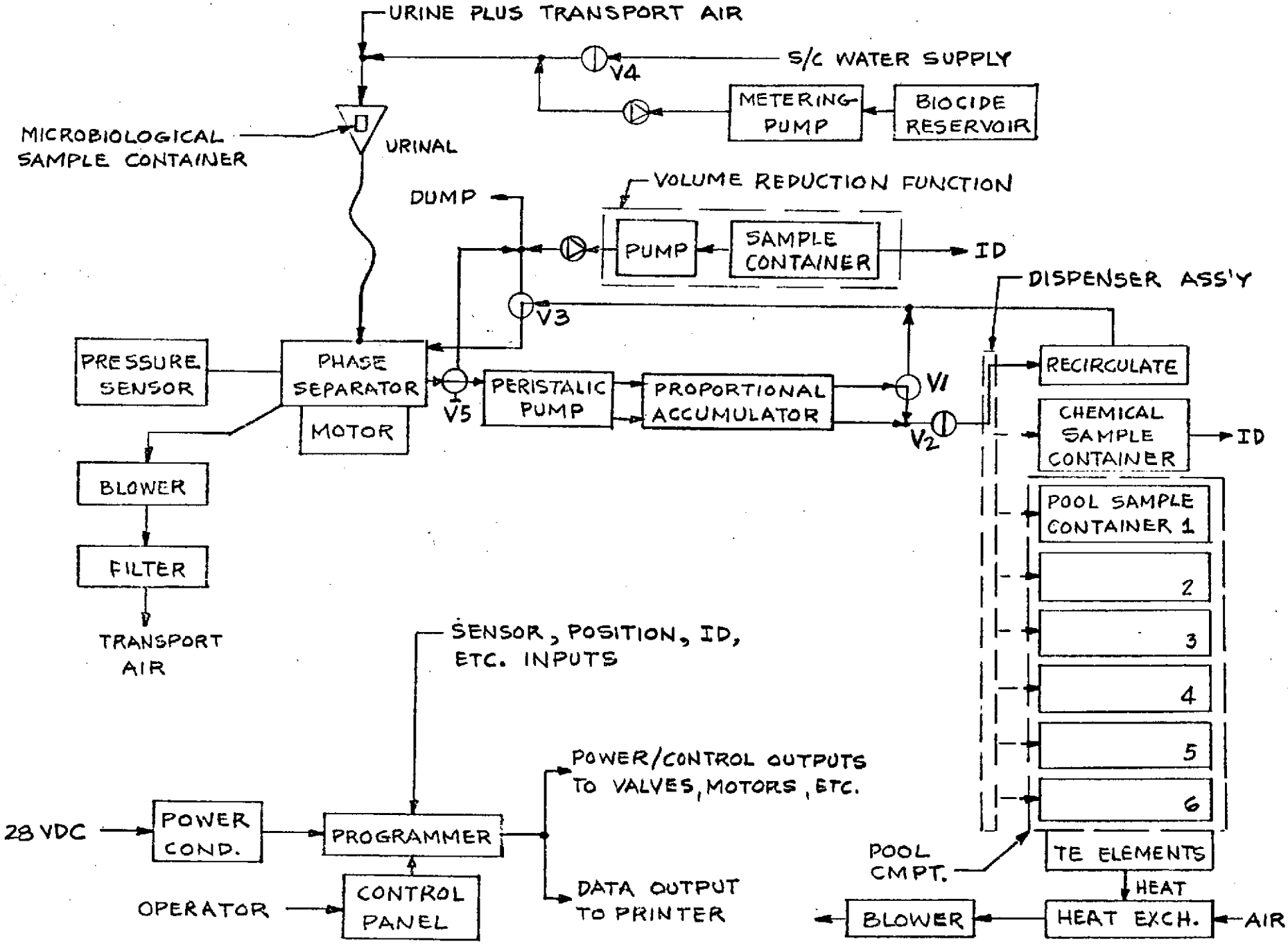


FIGURE 3.1.1.2-1 ABSS URINE SUBSYSTEM BLOCK DIAGRAM

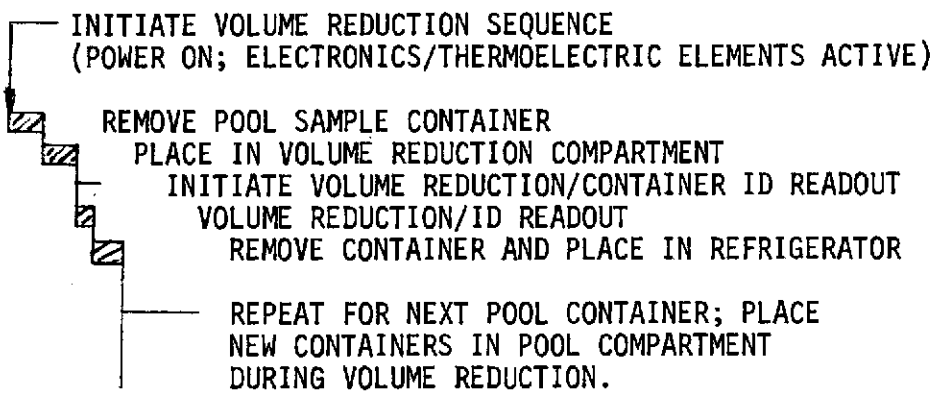
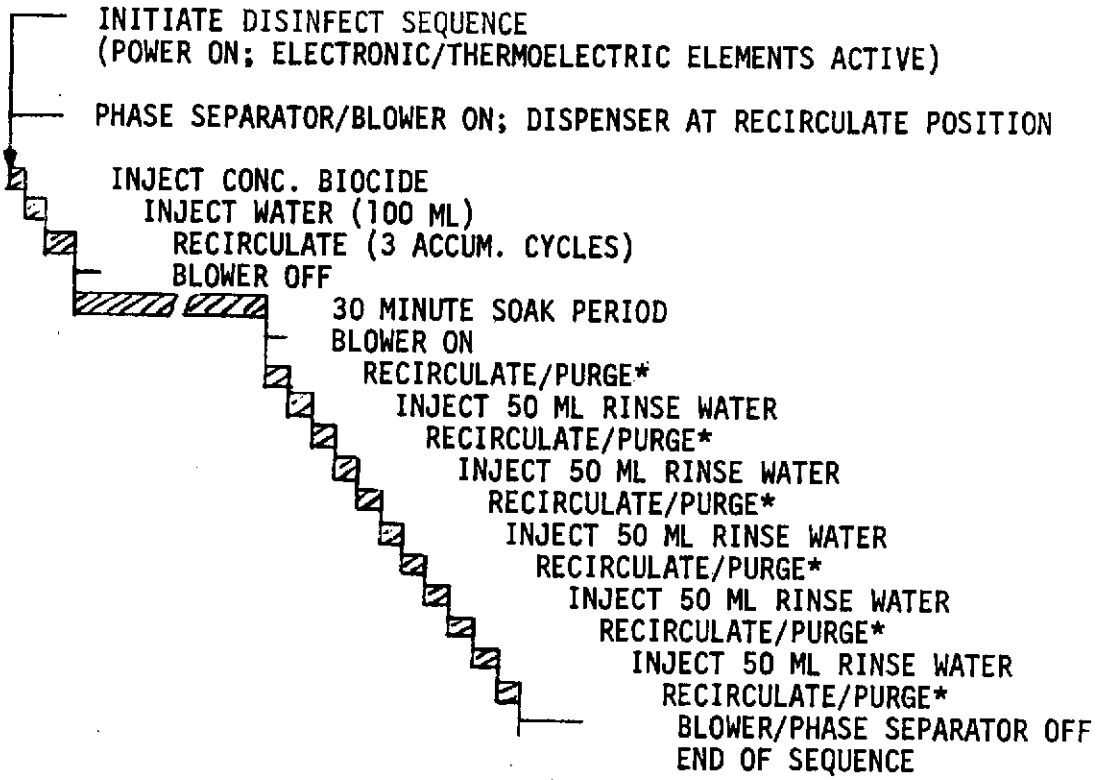


FIGURE 3.1.1.2-2(a) VOLUME REDUCTION SEQUENCE (NOT TO SCALE)



* 3 RECIRCULATE FOLLOWED BY 3 DUMP CYCLES OF THE ACCUMULATOR

FIGURE 3.1.1.2-2(b) DISINFECT SEQUENCE (NOT TO SCALE)

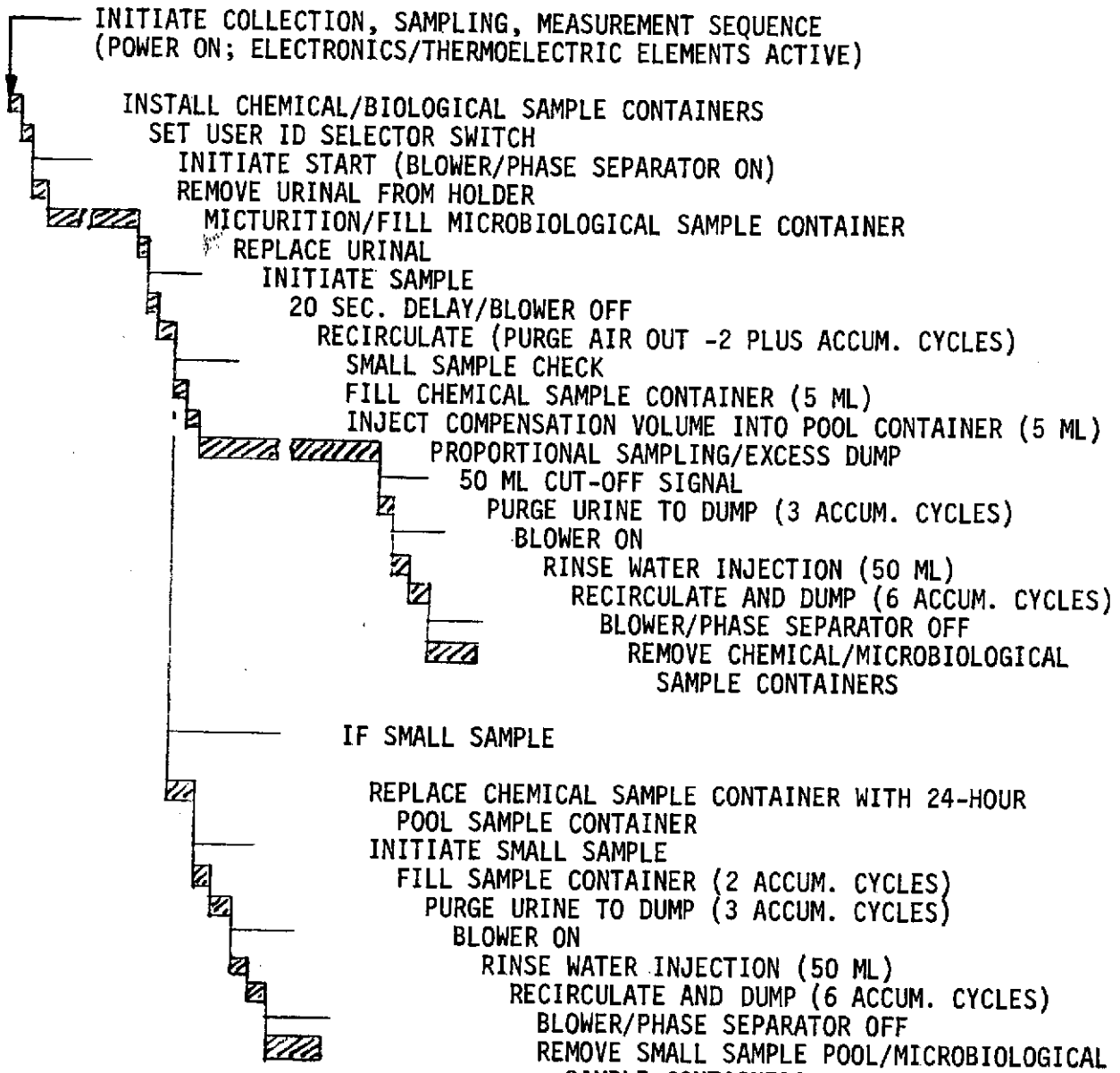


FIGURE 3.1.1.2-2(c) SAMPLING SEQUENCE (NOT TO SCALE)

3.1.1.2.3.2 Phase Separator Assembly

The function of the phase separator is to separate the urine from the transport air flow, mix the urine to ensure a homogenous sample and to temporarily store the urine prior to sampling. Specific design requirements are as follows:

a. Positive dynamic phase separation featuring a rotating impellor within a fixed external housing shall be used.
b. The selected motor shall be capable of driving the impellor at a constant speed (± 0.5%). The speed shall be anominal 400 rpm.
c. External diameter of the assembly shall be limited to 8.0 inches. The height shall be sized (less motor) to accommodate a maximum 1000 ml urine load.
d. A static type exit port (rather than tangential) for sensing pressure shall be provided.
e. Flow passages shall be sized to be compatible with a 4 CFM transport air flow, an entering urine flow of 45 ml/second maximum and an exit urine flow of 1.25 ml/second.
f. The impellor shall have eight vanes.
g. Voltage input to the motor (and associated rpm controller) shall be a nominal 28 volts dc.
h. All metallic materials in direct contact with urine and/or biocide flush solution shall be stainless, preferably type 316.
i. A debris filter shall be incorporated into the impellor.

3.1.1.2.3.3 Blower Assembly

The blower assembly shall provide the transport air flow into the urinal, through the phase separator and out through the filter assembly. Specific design requirements are as follows:

a. The assembly shall be capable of providing a 4 CFM transport air flow at 5 inches of water pressure head.

b. Voltage input shall be a nominal 28 volts dc.

3.1.1.2.3.4 Filter Assembly

The function of the filter assembly is to trap airborne aerosols and bacteria prior to the return of the transport air to ambient. Specific design requirements are as follows:

a. The bacteria control medium shall remove 98% of all particles 0.04 micron in size and larger, and 100% of all particles in excess of 0.6 micron size.

b. The assembly shall be configured for replacement of the filter medium.

c. Pressure drop through the filter assembly at 4 CFM shall be less than 1.0 inches of water.

3.1.1.2.3.5 Accumulator Assembly

The accumulator assembly is used as the urine volume measuring device. The assembly is also used to automatically split the measured volume into two parts, a retained sample which is collected in the 24-hour pool sample container and the remainder which is directed to a downstream waste management or water recovery system (not part of the Urine Subsystem). The assembly consists of a dual chamber accumulator, a pump for filling the accumulator and control valves. Specific requirements are as follows:

a. The accumulator shall be sized for a total of 25 ml per stroke (22.5 ml for the larger chamber and 2.5 ml for the small chamber).

b. The accumulator shall incorporate a spring return capability with a nominal force equivalent to 2 psi pressure at the exit ports at the end of the discharge cycle.

c. The accumulator shall provide integral limit switches (for operating control valves and pump) to control accumulator fill and discharge cycles.

d. The accumulator shall incorporate a displacement transducer. A voltage pulse shall be generated for at least each 0.5 ml of accumulator volume for a minimum total of 50 pulses per accumulator stroke.

e. Control valves shall be NC solenoid types operable on 28 VDC.

f. The pump shall be a multiple tube peristalic type operable on 28 VDC. Total discharge rate shall be a nominal 200 ml/minute.

3.1.1.2.3.6 Pressure Sensor

The output of the pressure sensor is used to enable start and termination of the Subsystem measure and sample action. Specific design requirement are as follows:

a. Pressure sensing range shall be 0 to 2.77 inches of water (0.1 psi).

b. Sensor output shall be linear and directly proportional to the sensed pressure. An increasing pressure shall result in an increasing output.

c. Frequency response shall be flat to 100 Hz.

d. Performance shall not be degraded by long-term exposure to urine and sustained pressure excursions to 20 inches of water.

e. Output voltage shall be approximately 5.0 volts at 0.1 psi.

3.1.1.2.3.7 Sample Containers

3.1.1.2.3.7.1 24-Hour Pool Sample Container

The 24-hour pool sample container consists of a rubber septum enclosed flexible plastic bag and identification tab. Specific requirements are as follows:

a. The replaceable container shall be sized to accept a maximum 400 ml representative 24-hour urine sample, i.e., 10% of each micturition for a specific subject.

b. The sample container shall be designed for sterilization and evacuation of residual air prior to use.

c. The filled sample container shall be capable of normal handling without leakage.

d. The sample container shall be configured to be compatible with a cold plate for cooling the collected urine.

e. A rubber septum/needle arrangement shall be used for connecting the sample container void volume into the subsystem.

f. Each sample container shall be serially numbered (alphanumeric and BCD format) and compatible with an optical reader via the identification tab.

g. At use, the identification tab shall be automatically coded to provide later correlation with the user subject.

h. The container materials shall not react with the urine sample.

3.1.1.2.3.7.2 Small Micturition Sample Container

Sample containers for under 50 ml urine samples shall be identical to those for the 24-hour pool samples.

3.1.1.2.3.7.3 Chemical Sample Container

The Chemical Sample Container shall be functionally identical with the 24-hour Pool Sample Container except the container shall be sized to accept a nominal 5 ml urine sample. All other requirements of 3.1.1.2.3.7.1 shall apply (except (g)).

3.1.1.2.3.7.4 Microbiological Sample Container

The Microbiological Sample Container mates with the Urinal Assembly and consists of a rigid protective canister enclosing screen supported adsorbent material. Specific requirements are as follows:

a. The adsorbent material shall be sized to acquire a nominal 2 ml of urine from a specific micturition.

b. During installation, removal and transport by the operator, the protective canister shall prevent possible contamination of the adsorbent material.

c. Removal of the urinal assembly for use shall automatically ready the adsorbent material for acquiring the desired urine sample; replacing the urinal shall automatically reinsert the adsorbent (and urine) into the protective canister.

d. The sample containers shall be serialized (alphanumeric only) and used with the correspondingly numbered Chemical Sample Container. Optical readout of the serial number is not required. User identification shall be assumed to be the same as the correspondingly numbered Chemical Sample Container.

e. The sample container materials shall not react with the sample.

f. Internal surfaces of the protective canister and the adsorbent material shall be sterile prior to installation.

3.1.1.2.3.8 Biocide Reservoir Assembly

The biocide reservoir assembly consists of a reservoir of concentrated biocide and a metering pump and flow control valve for automatically mixing and injecting into the urinal assembly the desired quantity of biocide. Specific design requirements are as follows:

a. The assembly shall be designed to store a minimum of 200 ml of concentrated biocide.

b. The biocide shall be a 50% solution of Betadine.

c. A nominal 7 ml of the concentrated biocide shall be injected via the metering pump to sterilize the subsystem at the end of each 24-hour use period.

3.1.1.2.3.9 Dispenser Assembly

The dispenser assembly consists of a moveable platform (2-axis) for transversing and indexing a urine dispensing "needle". The dispenser assembly automatically permits the transfer of urine from the accumulator to the appropriate sample container. Specific requirements are as follows:

a. The dispenser assembly shall automatically connect the accumulator output to one of 8 locations as required during a complete cycle. Location No. 1 shall provide for urine recirculation to the phase separator. A second location (No. 8) shall connect to the chemical sample container and the remaining six locations to 24-hour pool sample containers (one for each subject).

b. Connection to locations 1 and 8 shall occur automatically and sequentially (from 1 to 8) as part of each urine sampling cycle; connections to locations 2 through 7 (24-hour pool containers) shall occur automatically (from location 8) with the specific location preselected by the operator prior to start of the cycle.

c. Limit switches or equal shall be included to insure proper indexing and a leak proof connection of dispenser and sample container.

d. The dispenser assembly connector shall be a replaceable needle compatible with the sample container septums.

e. The time required to move from location No. 1 to any alternate location shall not exceed 15 seconds.

f. Traversing and indexing shall be accomplished by electrically powered elements operating on 28 volts dc.

g. Position sensors and/or limit switches shall be provided to prevent discharge of liquid if the dispensing needle has not properly mated with the appropriate septum.

3.1.1.2.3.10 Pool Compartment

The pool compartment provides refrigerated storage space for the six 24-hour pool sample containers. Specific design requirements are as follows:

a. The temperature within the pool compartment shall be maintained between 5 and 10°C to prevent deterioration of the urine samples.

b. Heat rejection shall be accomplished by use of a cold plate thermoelectrically cooled and with a heat rejection capability of 10 watts.

c. Temperature within the compartment shall be thermostatically controlled.

d. The sample containers shall positively contact the cold plate; mechanical pressure applied to the sample container shall not exceed 1 psi equivalent back-pressure.

e. An optical readout ID sensor shall be incorporated at the chemical sample container position to readout and correlate container number and user identification.

f. The sample containers shall be positioned to be compatible with the dispenser assembly.

g. At installation; each pool sample container shall be automatically coded with the corresponding position location (for later user correlation by the volume reduction assembly).

3.1.1.2.3.11 Volume Reduction Assembly

The function of the volume reduction assembly is to automatically remove excess urine from the 24-hour pool sample containers and to simultaneously read-out and correlate sample container number with user identification.

Specific requirements are as follows:

a. The volume reduction assembly shall be compatible with 24-hour pool sample containers containing up to 400 ml of urine.
b. On command, the contained urine volume shall be reduced automatically to 110 $\pm$ 10 ml, the excess urine directed to the dump line.
c. An optical readout ID sensor shall be incorporated to readout and correlate container number and user identification.
d. Position interlocks shall be provided to prevent operation of the volume reduction pump if the container is not properly positioned.
e. The volume reduction sequence shall not exceed 10 seconds per container (plus manual insertion and removal time).

3.1.1.2.3.12 Programmer Assembly

The programmer assembly shall provide the necessary functions for automatic operation as well as the counting and scaling circuitry necessary for proper presentation to the external recorder (printer). Upon activation of the SAMPLE switch the programmer will circulate the urine and will then sum the count pulses obtained from the displacement transducer of the accumulator assembly. The counts thus obtained will be stored in BCD format and displayed alphanumerically on the recorder print out. Specific design requirements shall be as follows:

a. The programmer assembly shall provide completely automatic operation after the SAMPLE switch is activated. After the water rinse phase, the programmer will allow the system to be reset for the next sampling sequence. Prior to the completion of the water rinse phase, it will not be possible to reset the programmer, i.e., restart the sampling sequence.

b. All switch closure inputs to the programmer assembly shall be buffered by digital switching to eliminate contact bounce.

c. The input counter shall be capable of accepting at least 3,000 counts. Its output shall be 12 binary lines for driving the recorder printer.

d. A pressure comparator circuit shall be provided which accepts the input from the pressure transducer and provides a 5 volt output whenever a minimum adjustable pressure level is exceeded.

e. The programmer assembly shall derive its input power from the power supply assembly.

3.1.1.2.3.13 Power Supply Assembly

The power supply assembly shall provide the following AC and DC voltages from a nominal 28 VDC input:

Voltage	Frequency	Power
26 volts	400 Hz	10 watts
+5 volts	DC	5 watts
±15 volts	DC	5 watts
±10 volts	DC	5 watts

Specific design requirements are listed in the following sections:

3.1.1.2.3.13.1 + 5 VDC Power Supply

a. The input to the +5 VDC power supply shall be 28 ±2 VDC.

b. The output of the +5 VDC power supply shall be +5 VDC ± 1% at 1 amp.

c. The regulation of the +5 VDC power supply shall be 0.1% line or load.

d. The ripple contained in the +5 VDC power supply shall be less than 1.0 mv.

e. The output of the +5 VDC power supply shall be capable of withstanding a short circuit to ground indefinitely at 25°C.

f. The +5 VDC power supply shall be capable of operating from 0 to 60°C with no more than ± 3% change in output voltage.

3.1.1.2.3.13.2 + 15 VDC Power Supply

a. The input to the ± 15 VDC power supply shall be 28 ± 2 VDC.

b. The output of the ± 15 VDC power supply shall be ± 15 VDC ± 1% at 150 ma.

c. The regulation of the ± 15 VDC power supply shall be 0.1% line or load.

d. The ripple contained in the ± 15 VDC power supply output shall be less than 1 mv.

e. The output of the ± 15 VDC power supply shall be capable of withstanding a short circuit to ground indefinitely at 25°C.

f. The ± 15 VDC power supply shall be capable of operating from 0 to 60°C with no more than a ± 3% change in output.

3.1.1.2.3.13.3 DC to AC Inverter

a. The input to the DC-AC inverter shall be 28 ± 2 VDC.

b. The output of the DC-AC inverter shall be 120 VAC at 400 Hz, and 26 volts VAC at 400 Hz.

3.1.1.2.3.13.4 ± 10 VDC Power Supply

a. The input to the ± 10 VDC power supply shall be 28 ± 2 VDC.

b. The output of the ± 10 VDC power supply shall be 10 VDC ± 3% @ 0.5 amps.

c. The regulation of the ± 10 VDC power supply shall be + 2% line or load.

d. The ripple contained in the 10 VDC power supply shall be less than 200 mv.

e. The output of the ± 10 VDC power supply shall be capable of withstanding a short circuit to ground indefinitely at 25°C.

f. The + 10 VDC power supply shall be capable of operating from 0 to 60°C with no more than a ± 3% change in output voltage.

3.1.1.2.3.14 Position Sensors

The position sensors indicate when the dispenser assembly (3.1.1.2.3.9) is at the desired location. Each sensor consists of a gallium arsenide light emitting diode and a silicon phototransistor. Specific design requirements shall be as follows:

a. Diode excitation shall be 10 $^{+5}_{-2}$ MA.

b. Phototransistor output shall be 300 μa minimum when the output is "on" and 1 μa maximum in the "off" state.

c. The sensors shall operate over a temperature range of 0 to 60°C.

3.1.1.2.3.15 Motor Drives

The motor drives will control the motors that position the dispenser assembly and engage and disengage the dispensing needle. Reversal of the motor direction is accomplished reversing the polarity of the DC voltage applied to the

3.1.1.2.3.15 Motor Drives (Continued)

motors. Specific requirements are as follows:

a. 28 ± 2 VDC @ 100 MA shall be provided to drive the motor.
b. Power to the needle motor will be interrupted when limit switches indicate the needle is fully engaged or fully retracted.
c. Power to the carriage drive will be interrupted when the position sensors indicate the desired position has been reached.

3.1.1.2.3.16 Container ID Sensor

The container ID sensors are used to read the container number and the user ID number. The container number is a three digit decimal number in BCD format; therefore, twelve (12) sensors are required to read the number. The user ID number is a three bit code used to identify one of the six users. The characteristics are similar to those described under "Position Sensors" (3.1.1.2.3.14).

3.1.1.2.3.17 Control Panel

The control panel layout shall conform to Figure 3.1.1.2-3.

3.1.1.2.3.18 Structure Assembly

A structure assembly shall be provided for mounting and supporting the Operating Model components. Specific design requirements shall be as follows:

a. The structure assembly with other system equipments installed, shall conform to the overall envelope dimensions of 3.1.1.2.1.
b. Specific equipments shall be located to minimize potential EMI problems and length of plumbing runs consistent with normal maintenance requirements.

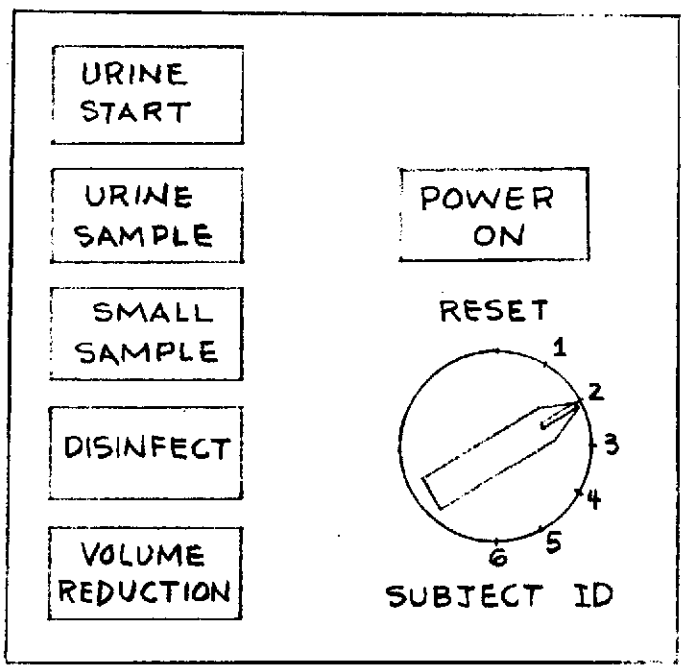


Figure 3.1.1.2-3 Control Panel Layout (Not To Scale)

c. The control panel shall be top mounted (14 x 14 inch envelope surface); pool compartment access via a front panel (14 x 24 inch envelope surface); either or both sides shall incorporate access panels to facilitate normal maintenance.

d. The structure shall accommodate positioning of the urinal (and its connecting hose) up to 10 inches from the upper surface of the structure.

e. The structure assembly shall be designed to withstand normal laboratory use.

3.1.1.2.4 System Operation

The Urine Subsystem Operating Model shall conform to the following operational sequence (Reference Figures 3.1.1.2-1, 3.1.1.2-2 and 3.1.1.2-3).

3.1.1.2.4.1 Power ON

a. Power ON switch actuated by user.

b. Power ON indicator light activated.

c. Subsystem electronics, e.g., power conditioning, internal clock activated (mission time starts when power ON initiated).

d. 28 volts dc applied to thermoelectric cooling circuit.

e. All pumps and valves deenergized; dispensers at initial positions.

3.1.1.2.4.2 Sample Container Installation

a. At beginning of each 24-hour period, manually install one to six 24-hour pool sample containers, depending upon the number of subjects involved, in the pool compartment. The container ID tab is marked automatically at installation with the corresponding position location.

b. Priorto each micturition, manually install a chemical sample container in the pool compartment.

c. Prior to each micturition, manually install a microbiological sample container in the urinal assembly. To facilitate later subject/-container/use time correlation, the microbiological and chemical sample containers shall be coded in pairs, each pair with identical numbers.

d. Steps (b and c) or (c) may be omitted as desired.

3.1.1.2.4.3 Cycle Initiation

a. The user sets the Selector ID switch to the appropriate location via RESET position. This action provides sample container and micturition volume correlation as well as directing a portion of the micturition to the appropriate 24-hour pool sample container. START switch inoperative until the sequence of back to RESET and then to the appropriate ID number has been accomplished.

b. START switch actuated by user.

c. START switch indicator light activated. If 3.1.1.2.4.3(a) ID selection not via reset, START switch indicator light goes to flashing condition and subsystem operation inhibited. Light OFF when ID selected as in 3.1.1.2.4.3(a).

d. Phase separator and blower activated. If phase separator is not at operating rpm within one second, START switch indicator light goes to flashing condition and further subsystem operation inhibited.

e. Verify engagement of dispenser and recirculate position. If verification lacking, START switch indicator light activated to flashing condition and dispenser driven to recirculate position. Inhibit further subsystem operation until engagement verified. At verification, light OFF and manual reactivation of switch necessary to reinstate sequence.

3.1.1.2.4.4 Collection

a. Urinal removed by user.

b. Micturition by user.

c. Phase separation, e.e., removal of transport air, occurs concurrently with micturition.

d. At completion of micturition; user replaces urinal.

3.1.1.2.4.5 Measure and Sample

a. SAMPLE switch actuated by user.

b. If designated 24-hour pool container not in place, SAMPLE switch indicator light activated to flashing condition and further subsystem operation inhibited until installation of container verified. Also, if urinal not replaced, SAMPLE switch light flashes and subsystem operation inhibited until installation verified. After verification, SAMPLE switch light OFF and manual reactivation of switch necessary to reinitiate sequence.

c. SAMPLE switch indicator light actuated.

d. Blower deactivated.

e. 14 to 21 second delay initiated.

f. During the delay period, recirculation to purge air bubbles from the lines, peristalic pump, valves and accumulator is accomplished as follows: Peristalic pump is energized and valves V1 and V2 remain deenergized. This sequence causes the accumulator pistons to move from the empty to full position thereby drawing fluid from the phase separator. When the accumulator full (discharge) limit is reached, the pump is deenergized and V2 is energized (OPEN). The urine then flows from the accumulator through the dispenser (recirculate position)

and the deenergized V3 back into the phase separator. Fill and discharge of the accumulator automatically repeats until the end of the 14 to 21 second delay period plus the time required to completely discharge the accumulator.

g. After complete discharge of the accumulator is verified, the pressure switch output is interrogated to determine if the micturition is large enough to sample. If the pressure switch output indicates less than 50 ml of urine in the phase separator, a SMALL SAMPLE condition exists and the SMALL SAMPLE switch indicator light is activated to flashing condition. Further sampling activity stops until manual restart by the operator (See 3.1.1.2.4.6).

h. Assuming a micturition volume greater than 50 ml, the dispenser automatically traverses to and engages with the chemical sample container.

i. Fill the accumulator by energizing the peristalic pump and deenergizing valve V2.

j. When engagement of the dispenser and sample container and accumulator fill are verified, volume measurement (output of the accumulator volume transducer during discharge) is initiated.

k. A total of 5 ml of urine is discharged from the accumulator into the chemical sample container. This is accomplished by deenergizing the peristalic pump and energizing valve V2 and then deenergizing Valve V2 when 5 ml of urine have been discharged. Steps j and k automatically omitted if no chemical sample container is in place.

l. After valve V2 is deenergized, the dispenser moves automatically to engage the 24-hour pool sample container preselected by the user.

m. When engagement of the dispenser and sample container are verified, valve V2 is energized and 3.5 ml of urine discharged into the pool container. This 3.5 ml is a compensation volume and represents 10% of the 35 ml remaining in the phase separator at proportional sampling cut-off by the pressure switch (for micturation exceeding 50 ml).

n. After the compensation volume has been discharged, valves V1 and V3 are energized with the 10% accumulator chamber output directed to the pool container and the 90% chamber output to the dump connection. Alternate fill and discharge of the accumulator continues until the volume remaining in the phase separator (including line residual) is reduced to 35 ml as determined by the pressure switch. On fill, the peristalic pump is energized and valves V1 and V2 deenergized. On discharge, the peristalic pump is deenergized and valves V1, V2 and V3 energized.

o. When the 35 ml cut-off volume signal received, turn off peristaltic pump and energize valves V1 and V2 (i.e., stop accumulator fill and proportioning discharge). The total micturition volume is thus the sum of the accumulator volume transducer output for the above and previous discharge cycles plus 35 ml.

3.1.1.2.4.6 Small Sample

If a small sample condition occurs:

a. User removes (if in place) the chemical sample container and installs a 24-hour pool sample container in place of the chemical sample container.

b. User activates SMALL SAMPLE switch.

c. SMALL SAMPLE switch indicator light on but not flashing.

d. The dispenser automatically traverses to the normal chemical sample container position and engages with the special 24-hour pool sample container.

e. When engagement of the sample container and dispenser are verified, the peristalic pump is energized and valves V1 and V2 deenergized to fill the accumulator. On discharge the peristalic pump is deenergized and valve V2 (only) energized.

f. Complete two accumulator fill/discharge cycles.

3.1.1.2.4.7 Purge

a. At the 35 ml volume condition, (See 3.1.1.2.4.5(o) or after two SMALL SAMPLE accumulator fill/discharge cycles, valves V1 and V2 are deenergized.

b. The dispenser is returned to the recirculate position.

c. When engagement of dispenser and recirculate connection is verified, valves V1 and V2 are reenergized and accumulator discharge completed.

d. Perform three accumulator fill and discharge cycles with valve settings as in 3.1.1.2.4.5(n) above. This action removes most of the residual liquid from the subsystem.

e. Readout volume (accumulator transducer output), mission time, user ID and chemical sample container number and transmit to external printer (See Figure 3.2-2).

3.1.1.2.4.8 Water Rinse

a. Reactivate blower.

b. After 5 second delay, energize (OPEN) rinse water valve V4 for TBD seconds (inject 50 ml).

c. Recirculate for 2 accumulator fill/discharge cycles. Then purge out the rinse water until six accumulator fill/discharge cycles have been completed (valve settings as per 3.1.1.2.4.5(n) except every other cycle valve V1 deenergized during discharge.

3.1.1.2.4.9 Shut-Down

a. At end of water rinse purge, subsystem automatically reverts to pre-START condition, i.e., phase separator and blower OFF and all valves and dispenser deenergized.
b. START, SAMPLE, and SMALL SAMPLE (if used) indicator lights deactivated.

3.1.1.2.4.10 Sample Container Removal

3.1.1.2.4.10.1 Microbiological and Chemical Sample Containers

a. After each micturition, manually remove microbiological and/or chemical sample container(s).
b. Manually record container serial number and subject ID.

3.1.1.2.4.10.2 24-Hour Pool Sample Container

a. At the end of each subsequent 24-hour interval or as desired, manually remove used 24-hour pool Sample Containers. Container serial number and user ID are correlated during Volume Reduction (3.1.1.2.4.11).

3.1.1.2.4.11 Volume Reduction

a. Manually insert a used 24-hour pool container into the volume reduction assembly and close access door.
b. VOLUME REDUCTION switch activated by operator.
c. VOLUME REDUCTION switch indicator light and dispenser drive activated.

d. After engagement of dispenser and sample container verified, start volume reduction pump and operate until shut-off signal from 110 ml volume limit switch.

e. Simultaneously, readout and send to external printer container serial number, mission time, and user ID (See Figure 3.2-2).

f. Disengage dispenser from sample container.

g. After disengagement verified, VOLUME REDUCTION indicator light deactivated.

h. Sample container manually removed and placed in sample container.

i. Repeat for each used container.

3.1.1.2.4.12 Subsystem Sterilization

Initiate subsystem disinfection in conjunction with sample container removal from pool compartment.

a. DISINFECT switch actuated by user.

b. DISINFECT switch indicator light activated.

c. Readout mission time and transmit to external printer (See Figure 3.2-2).

d. Reactivate blower and phase separator, all valves deenergized. Verify that urinal is in stowed position. If not in position, DISINFECT switch indicator light flashes and further disinfection activity inhibited until urinal in position. After verification, light OFF, manual reactivation of DISINFECT switch required to reinitiate sequence.

e. Deactivate accumulator.

f. After verification that dispenser is correctly connected and at the recirculate position, operate biocide pump for TBD seconds (inject 7 ml).

g. Deenergize biocide pump and energize (OPEN) rinse water valve V4 for TBD seconds (inject 100 ml).

h. Reactivate accumulator and recirculate the biocide sterilization solution until two accumulator fill/discharge cycles have been completed (valve setting sequence as per 3.1.1.2.4.5(f) except energize V1 valve during one discharge.

i. Deactivate blower.

j. After 30 minute delay, reactivate blower and purge out the biocide sterilization solution using six accumulator fill/discharge cycles (valve settings as per 3.1.1.2.4.5(n) except every other cycle valve V1 deenergized during discharge; Valve V3 open to dump.

k. Deactivate accumulator.

l. Energize rinse water valve V4 (OPEN) for TBD seconds (inject 50 ml water).

m. Repeat (h).

n. Purge using six accumulator fill/discharge cycles (valve settings as per 3.1.1.2.4.5(n) except every other cycle valve V1 deenergized during discharge; Valve V3 open to dump.

o. Repeat (k) thru (n) for a total of five rinse/dump cycles.

p. Blower/phase separator OFF; all valves deenergized; DISINFECT switch indicator light deactivated.

3.1.1.2.4.13 Emergency Operation

a. Open manual valve V5 to dump collected urine.

3.1.2 Operability

3.1.2.1 Reliability

Operating Model reliability shall be achieved by reliance on maintenance procedures rather than redundancy.

3.1.2.2 Maintainability

The Operating Model shall be designed to provide component accessibility, replaceability and serviceability consistent with the intended use.

3.1.2.3 Useful Life

The Operating Model shall be designed for a minimum useful laboratory life, with maintenance, of 12 months.

3.1.2.4 Operating Environment

The Operating Model shall be designed to operate under conditions normally encountered in engineering or physiological test laboratories.

3.1.2.5 Human Engineering

Human Engineering factors shall be considered in the design and layout of the Operating Model.

3.1.2.6 Safety

3.1.2.6.1 User Safety

The Operating Model shall be designed to prevent hazardous conditions and inadvertent operation. Specifically,

(a) Sharp edges, corners or equal shall be eliminated.

(b) All electrical junction points shall be insulated or otherwise covered to prevent accidental contact.

(c) All components shall be grounded to the structure with provisions on the structure for connecting to an external ground provided.

3.1.2.6.2 Equipment Safety

The Operating Model shall incorporate fail-safe features. Specifically, fault isolation protection shall be provided as required. Consideration shall also be given to protecting electrical circuits from inadvertent urine leakage.

3.2 Interface Requirements

3.2.1 Feces/Storage Subsystems

The Urine Subsystem Operating Model shall be capable of functioning with or independent of the Solids Subsystem Operating Model.

3.2.2 Electrical

The Operating Model shall operate on nominal 28 VDC power from an external source. Connection to the model shall be via a Bendix pygmy type connector.

3.2.3 Mechanical

The Operating Model shall be self-supporting (structurally).

3.2.4 Fluid

3.2.4.1 Water

The Operating Model shall be compatible with a nominal 15 to 40 psig external water supply. Connection shall be via a recessed 1/8 inch NPT (female) pipe fitting.

3.2.4.2 Waste Dump

The Operating Model shall be compatible with a 0 to 1.0 psig back pressure dump line. Connection shall be via a recessed 1/8 inch NPT (female) pipe fitting.

3.2.5 Recorder Printer

The operating model shall be capable of interfacing with an external recorder printer. The function of the printer is to provide a permanent record of the time and volume of each micturition. In addition the time of each sterilization and the identification of each sample bag will be printed. Specific requirements are as follows:

a. The printer shall have six (6) columns.
b. The input to each column will be four (4) TTL compatible lines in BCD format.
c. The print time shall be less than 500 MS.
d. The printer shall operate from a Standard 115 VAC at 60 Hz wall outlet and shall consume less than 100 watts peak.
e. The printer will print out the each individual micturition volume at the completion of the urine purge cycle. Sterilization time and container ID shall be printed on command.
f. Tape printout code shall conform to Figure 3.2-1 and 3.2-2.

3.2.6 User

The operating model shall be designed for use by male and female subjects.

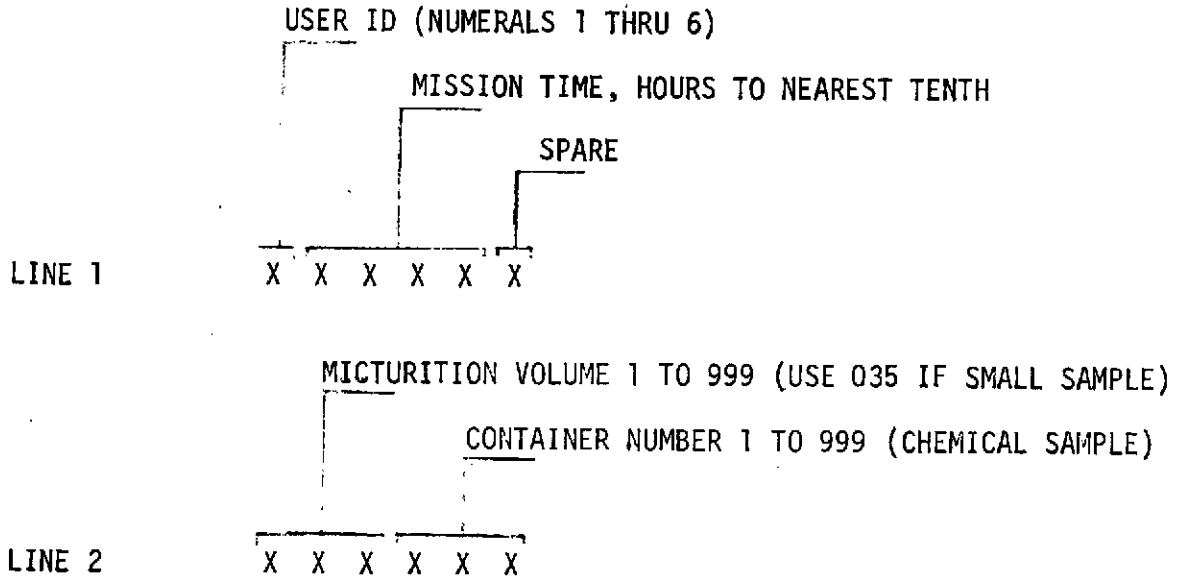
Direction of
Paper Travel

```
X X X X X X
X X X X X X
X X X X X X
X X X X X X
X X X X X X
X X X X X X
1 0 4 4 8 0 — USER 1 @ 44.8 HOURS; CONTAINER NO. 054; 942 ML MICTURITION VOLUME.
9 4 2 0 5 4
4 0 4 5 1 0 — USER 4 @ 45.1 HOURS; CONTAINER NO. 055; MICTURITION VOLUME UNDER 50 ML.
0 0 0 0 5 5
8 0 4 8 1 0 — VOLUME REDUCTION @ 48.1 HOURS; USER 1; POOL CONTAINER 063.
1 0 0 0 6 3
8 0 4 8 1 0
2 0 0 0 6 4
8 0 4 8 1 0
3 0 0 0 6 5
8 0 4 8 2 0
4 0 0 0 6 6
8 0 4 8 2 0
5 0 0 0 6 7
8 0 4 8 2 0
6 0 0 0 6 8
9 0 4 8 2 0 — STERILIZATION INITIATED @ 48.2 HOURS.
3 0 5 4 6 0 — USER 3 @ 54.6 HOURS; CONTAINER NO. 070; 427 ML MICTURITION VOLUME.
4 2 7 0 7 0
X X X X X X
X X X X X X
```

FIGURE 3.2-1 TYPICAL PRINTOUT

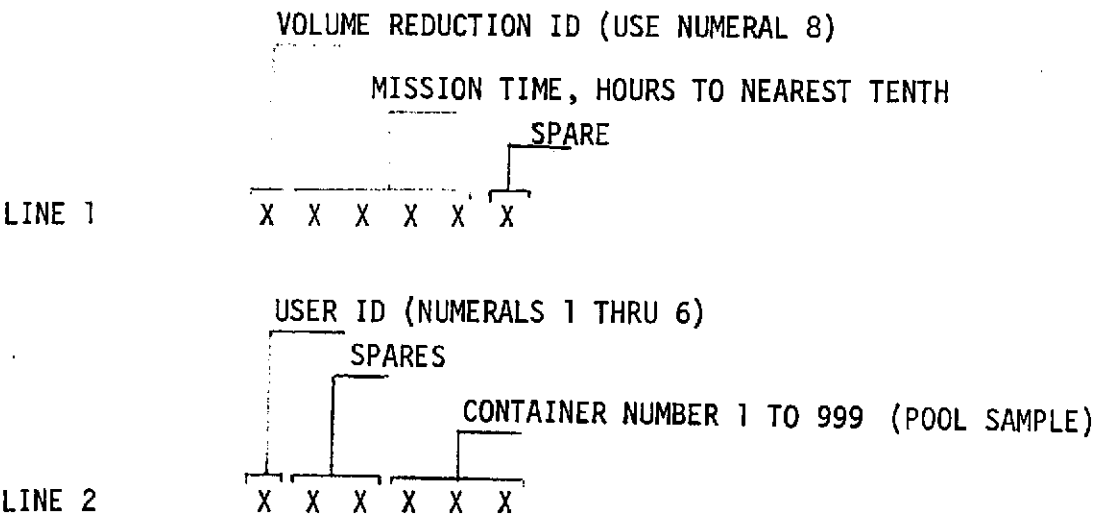
a) EACH MICTURITION

- TWO LINES:



b) VOLUME REDUCTION

- TWO LINES PER 24 HOUR POOL CONTAINER:



c) STERILIZATION

- ONE LINE:

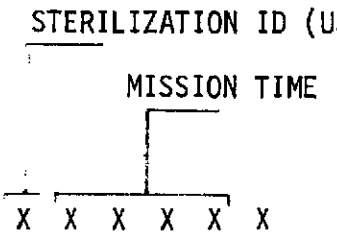


FIGURE 3.2-2 TAPE PRINTOUT CODE

4.0 TEST REQUIREMENTS

4.1 Quality Assurance

A minimal quality assurance program shall be performed consistent with the design status of the Urine Subsystem Operating Model. The intent of this effort shall be to provide valid background information for subsequent program phases. Specific requirements are as follows:

a. Perform a preliminary FMEA, with safety emphasized.

b. Maintain configuration control records, i.e., provide a good record of what was fabricated and tested.

c. Perform laboratory tests to compare actual performance with specification requirements.

d. Fabricate in accordance with good commercial practice.

4.2 Verification

The performance of the Urine Subsystem Operating Model shall be determined with specific development tests as follows:

a. Verify subsystem operating conditions/cycles, i.e.,

   (1) Power - ON/OFF

   (2) START

   (3) SAMPLE

   (4) SMALL SAMPLE

   (5) VOLUME REDUCTION

   (6) DISINFECT

b. Determine accuracy of volume measurement.

c. Determine accuracy of retained sample size (microbiological, chemical and reduced volume 24-hour pool samples).

d. Determine proportional sampling ratio.

e. Determine transport air flow rate.

f. Determine biocide solution/flush water quantities.

g. Determine residual biocide concentration in subsystem at end of disinfect cycle.

5.0 DATA LIST

Documentation pertaining to the Urine Subsystem Operating Model shall be provided as follows:

a. Specification Requirements

b. Top Assembly

c. Manufacturing Drawings for Fabricated Components

d. Vendor Data Sheets for Purchased Components

e. Wiring Diagrams

f. Verification Test Report (may be combined with (g))

g. Final Program Report.